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CONTENTS

Editorial 323

Research and Education.

Research-Mindedness Begets Research.

Measurement of Molecular Orientation in Fibres. D. R. Morey 325

Mercerization of Cotton for Strength. J. B. Wilkie 346

Textile Foundation Researches 364

Abstracts 367

Bibliography 374

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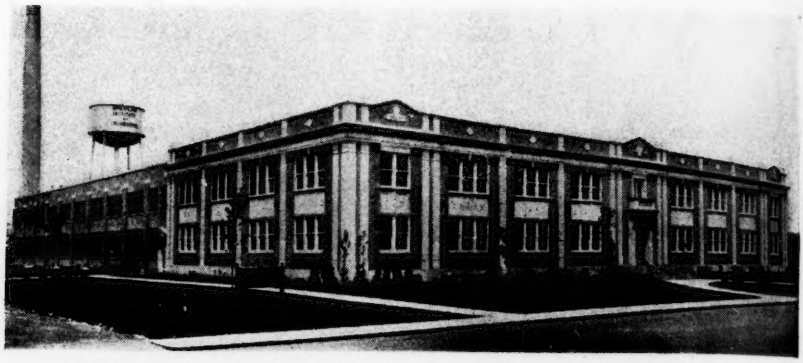

THE AMERICAN INSTITUTE OF LAUNDERING, JOLIET, ILL.

If the Textile Industry was as research-minded as the Laundry Industry!

This building, 304 x 178 ft., costing $430,000, is the plant of the American Institute of Laundering, controlled and operated by the Laundryowners National Association.

It houses research laboratories; a vocational school; a student training and research laboratory unit; a commercial laundry, illustrating the latest developments in equipment and practice; and library, administration and service departments.

The annual appropriation for research work is raised largely through dues of member laundries, at the rate of 50c per $1,000 of gross annual business, the minimum annual dues being $25.

Were textile manufacturers as research-minded as laundry-owners, and as skilled in cooperation, then, at the same rate and on only one-tenth of gross average textile sales, there could be made available annually for research $250,000. And that sum is less than one-tenth the amount annually spent for research by some individual chemical, electrical and communications companies.

U. S. I. T. R.* co-operates in promotion of research and research-mindedness.

* United States Institute for Textile Research, Inc.

TEXTILE RESEARCH

EDITORIAL

Research and Education

PROGRESS in scientific textile research in Great Britain, Germany and this country has already been sufficient to challenge the adequacy of textile literature and of the educational methods of the textile schools. Possibly, at the moment, the transitory status of much of our scientific textile knowledge may justify authors and publishers in delaying revision of textile books and publication of up-to-date treatises. Lack of such literature, however, is not a legitimate excuse for failure of the industry to demand that the textile schools keep pace with scientific progress, and prepare for an era when textile students, who are to be the future mill technicians and managers, must have the broadened general education that will allow them to understand and apply the new scientific knowledge that is becoming available.

Albert Abbott, an eminent British authority on technical education and research, spoke as follows on this subject in a recent address: "It is impossible to suppose that an industry which has established four great Research Associations for the scientific investigation of its problems will remain contented to have its mills and works staffed by responsible officials who are not fully competent, from their abilities and attainments, to utilise the results obtained by these Associations. It ought to demand, and I believe that it will demand, that these officials shall have received a technical education of the very best type, namely, one based on a prolonged general education. Unless it does, much of the expenditure on scientific research will have been wasted, and the industry in which we are all so greatly interested will not increase in efficiency. This is a prospect which none of us can contemplate with equanimity."

These matters are of profound importance to the textile industry and to those dependent upon its future prosperity. But, as Mr. Abbott concluded, they are matters to be solved by the manufacturers themselves, not by the educators. First, the manufacturers must show that they want the problems solved, and then they must co-operate with the educational institutions in their solution.

Research-Mindedness Begets Research

THE founders of U. S. Institute were well aware that it would be impossible to finance co-operatively a well-rounded research program until there was more general appreciation by manufacturers of the value of scientific research to the textile industry. U. S. Institute's major activity thus far, therefore, has been the promotion of research-mindedness.

Although a large part of the industry is yet to be "sold" on scientific research as one of its necessary activities, courage to increased sales effort may be gained from the fact that the British Cotton Industry Research Association, the largest of the four British textile research associations, emphasizes in its last annual report that: "The winning of the cotton industry *as a whole* to a full appreciation of the value to it of scientific research is perhaps the biggest problem facing the Association." There is also circumstantial evidence that the other British textile research associations concur in this statement.

These British research associations were organized from twelve to fifteen years ago and have been actively engaged in research work for a decade or more. Until recently they were wholly financed by grants of the British Department of Scientific and Industrial Research from the Imperial Trust Fund. This fund having approached exhaustion last year, and additional government grants being insufficient to finance all of the research associations on their previous scale of expenditures, it has been necessary for them to go to their industries for support. It is their experience in efforts to secure industrial support, under distressing business and financial conditions, that has awakened them to the need of "winning industry to a full appreciation of the value to it of scientific research."

The Measurement of Molecular Orientation in Fibres

By D. R. MOREY *

Foreword

I WOULD feel guilty to present this report without some attempt at making it more readable to my friends in other fields, so I will set down here, as a sort of appendix, a little description of things which will later on be discussed, assuming that the reader understands them quite well. What follows here need not concern the physicist; he may turn at once to the start of the report proper.

We are concerned primarily with light and its relation to matter. Under certain conditions an atom may possess more than its normal amount of energy and send it out in the form of a bit of light. Just what happens within the atom when it gives up energy by sending out light is not known, although there are some useful theories. For our purposes the so-called classical picture of a vibrating electron is best suited: An electron oscillates back and forth on a certain path, and in so doing sends out a train of electromagnetic waves. An analogy is that if we grasp a stretched rope and move our hand up and down, transverse waves will travel along the rope away from the hand. The extra energy originally stored in the atom is converted to energy of wave motion. The quantum theory tells us that energy is sent out only in certain definite amounts, but this need not concern us.

We will observe that, if the hand motion on the rope is up and down, the wave motion is up and down; the waves travel in a vertical plane. Such a wave is a plane-polarized wave. If we were to think about light we would describe the wave motion as plane-polarized, with the electric vector vertical. An ordinary unpolarized beam of light comes from a great number of oscillators all having different directions of motion; hence, the light vibrations are no longer confined to one plane. A polarized beam consists of a number of wave trains having the same direction of vibration, and may be produced from ordinary light by a Nicol prism (in this work a Glan-Thompson prism) which transmits wave trains having vibrations in a certain plane, and stops all others.

The absorption of light is a very common phenomenon, responsible for our colored fabrics, for our ability to see type on a printed paper. It is a sort of reverse process to light emission. Radiant energy strikes an atom, and, because of some mechanism within that atom, is changed to another form. In most cases the energy eventually appears as heat imparted to the absorbing material. In some cases a chemical change is produced, and, in a few cases, fluorescence. We will discuss this presently.

Usually, an absorbing material (a piece of colored glass for example) absorbs the same fraction of the incident energy regardless of the direction

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of vibration of the light waves falling on it. There are some cases, however, in which a material (most always a crystal) has a different absorptive power for different directions of vibration of the light falling on it. With wavelength (color) and intensity of an incident polarized beam of light fixed, the absorption is found to change as the direction of vibration of the waves is turned with reference to the crystal. This *dependence of absorption on direction of vibration* masquerades under the names "dichroism" and "pleochroism," and has these names because, in many cases, the color of the transmitted light changes as the plane of polarization is rotated. This production of "two colors" or "many colors" is merely a result of an underlying phenomenon, and its absence is not proof of the absence of a dependence of absorption on vibration direction.

When an atom takes on additional energy by absorbing a "quantum" of light, it succeeds before long in getting rid of it; in most cases converting it to heat, or the energy of random motion of its neighbors. One of the less common ways of losing this extra energy is to have the atom or molecule send it away as radiation. This is the basic process of *fluorescence*, and the secondary radiation which the atom or molecule sends off is known as fluorescent radiation, or simply fluorescence. In general, the amount of energy absorbed is somewhat greater than that radiated as fluorescence; the molecule exacts a certain percentage of the original energy as payment for its act. The exciting light, therefore, is of shorter wavelength than the fluorescence. The fluorescence is fixed in wavelength; for instance, if one excites a solution of rhodamine, first with green light, then with blue, then with ultra violet, one always obtains a fluorescent band in the orange and red. There is an extremely short time-interval between the absorption of light by a fluorescent molecule and the emission of fluorescence, and this is one of the distinguishing features between fluorescence and phosphorescence. A fluorescent material will not glow in the dark after removing it from the exciting light.

Dichroism, or Polarized Fluorescence

IF the phenomenon of dichroism, or polarized fluorescence, is to exist, the prime condition to be satisfied is that the absorptive or emittive mechanisms responsible for the optical phenomenon must be in at least a partial alignment. This general condition is more easily interpreted physically by stating it in the form of two more specific conditions:

(1) The absorptive or emittive mechanism of the molecule shall be uniquely fixed with respect to the attractive forces presented by the molecule to its neighbors.

(2) The molecules participating in the optical phenomenon shall possess at least a partial orientation or alignment.

The first condition means that the molecule must be anisotropic, or a sort of polar molecule; it must not present such a symmetrical appearance to external forces that it would react

similarly to them regardless of its orientation. Condition (1) also rules out the conception of the mechanism or oscillator being sufficiently unconstrained to absorb energy regardless of its position in space with respect to the direction of the electric vector of the exciting light. In the case of a number of dyestuffs there is experimental proof that the oscillator is constrained to a definite path within the molecule. This proof is found in the behavior of polarized fluorescence of dyestuff solutions, when they are excited by polarized light.[1] Were the absorptive and emittive mechanisms not directively fixed in the molecule, the polarization should not depend upon or be related to the kinetic motion of the molecules. Experiment shows, however, that the polarization is dependent upon the temperature and viscosity of the solution, becoming smaller when the temperature and viscosity change in the direction of allowing greater Brownian movements.

The phenomenon is pictured in this way: Energy is absorbed from the plane polarized exciting radiation only by those molecules in the solution which lie in a position such that the absorbing mechanisms and the electric vector are in the proper relative position for absorption. This absorbed energy is emitted as fluorescent energy after a short time has elapsed (usually between 10^{-8} and 10^{-9} seconds, and called the mean life of the excited molecule). If, during this time, no collisions have occurred (little thermal agitation) which would displace the excited molecules from their original oriented positions, the absorbed energy will be emitted as partially polarized fluorescence. If, however, kinetic agitation is allowed to exist, some of the excited molecules will be displaced from their original aligned position (which is determined by the direction of the electric vector of the exciting light), to random positions, before fluorescing, and as a consequence the polarization of the fluorescent light is lessened. The agreement of experiment with predictions based upon this picture of the process is proof of its correctness and of the fulfillment of condition [1] with respect to the conception of a constrained oscillator.

The second condition is most fully satisfied by a single crystal, which, of all the various physical forms in which matter exists, possesses the most complete and perfect alignment or orientation of its molecules. At the opposite end stands the amorphous sub-

stance, and between these extremes there is a large variety of substances having varying degrees of orientation. In this latter class there are the vegetable and animal fibres such as ramie, cotton and wool, and the artificial fibre rayon. If the molecules of the material are able to absorb or fluoresce and if the material is crystalline, the second condition is satisfied, but if the material does not absorb radiation, foreign molecules, able to absorb or fluoresce, must be introduced into the medium in an oriented fashion if pleochroism or polarized fluorescence is to appear. In order that these introduced molecules shall be aligned, it is necessary, first, that the medium itself have an oriented character, so that the forces of attraction which it presents to the introduced molecules shall be uniformly directed, and, second, that the introduced molecules be polar, or, more generally, present an anisotropic condition to the aligned forces of the medium.

Earlier Work

The first recorded experiment depending upon these two conditions is that of Senarmont (Pogg. Ann. 1854) who produced crystals of hydrated strontium nitrate $Sr(NO_3)_2 4H_2O$ from a liquor containing logwood dye. The resulting crystals showed strong dichroism. Senarmont's experiment is a case of the alignment of foreign molecules by the forces of the true crystalline material, the absorptive properties residing in the foreign molecules. Dichroism can exist in crystals in which the absorption is carried on by the crystalline material itself. Such is the case for crystals of magnesium platinocyanide.

An experiment similar to that of Senarmont was performed by Ambronn [2] who crystallized sugar in a solution of Congo Red, and obtained dichroic crystals. He further observed [3] that freshly cut pieces of gypsum or Iceland spar placed in concentrated solutions of Congo Red or Methylene Blue acquired on the surface and in fine scratches an oriented crystallization of the dye. This is an excellent example of alignment of foreign molecules by oriented forces. The alignment in fact constitutes proof of the oriented nature of gypsum or Iceland spar. This seems so evident as to warrant no mention, but it is well to bring out the point now so that the similar interpretation which we shall make

in the case of fibres will be seen with better perspective, for the oriented forces within a fibre are by no means as self evident as those of a freshly cut surface of Iceland spar or gypsum. The film of impurities which soon collects on the surface satisfies the residual directed forces emanating from the crystal surface, and destroys its ability to produce orientation effects.

The term dichroism or pleochroism is used here to indicate the phenomenon of dependence of absorption coefficient on the plane of polarization of the light. Such dependence usually produces "two colors" or "several colors," but a change of color is not a necessary consequence. The first intensive study of artificially produced dichroism was made by O. Lehmann.[4] Lehmann grew a great number of organic crystals from solutions containing dyestuffs and other coloring materials, and then examined the crystals for dichroism. An examination of his results shows that the ability to satisfy conditions (1) and (2) varies considerably, and is a function both of the properties of the crystallizing material and the coloring matter added. Thus, of a number of organic materials having crystalline form, meconic acid seems best able to impart orientation to foreign molecules, for 37 different dyestuffs were found to color meconic acid crystals and produce strong dichroism, and only 11 coloring materials failed to color the crystals.

On the other hand, using hippuric acid as the crystallizing material, only 7 dyes were found which combined to form strongly dichroic crystals, while 25 dyes produced but weakly dichroic crystals and 10 did not color the crystals at all. With quinine sulfate, 3 coloring materials produced dichroic crystals, 5 produced very weak dichroism and 39 produced no coloration. Papaverin stands at the end of the long list of materials used by Lehmann, for only two dyes produced dichroic crystals, 4 produced colored but non-dichroic crystals, and 39 produced no coloration.

Pleochroism in Dyestuffs

As to the dyestuffs, extreme examples are found in Congo Red, usually among those producing dichroic crystals, and Fluorescein, almost without exception in the class producing weak or no dichroism, or in the class producing no coloration at

all. The conclusion is immediately reached that Congo Red is quite anisotropic and displays marked affinity for other materials (in agreement with the fact that it is a direct dye of the textile industry) while Fluorescein is rather symmetrical as regards its external fields which cause it to adhere to other molecules, and these external fields are much weaker than those of Congo Red.

The phenomenon which, with dichroism, is a consequence of the simultaneous fulfillment of the two conditions, is polarized fluorescence. Even the case of polarized fluorescence from liquids is strictly in accord with the two conditions. It would seem that in a liquid there could be no net orientation, and, hence, the second condition be impossible of fulfillment. But only those molecules radiate which are similarly oriented so as to be able to absorb energy from the exciting beam, and this fact accounts for the alignment. The earliest recorded observation of polarized fluorescence was made by Grailich (1858) [5] on crystals of the platinocyanide salts, but until 1896 no intensive study was made of the phenomenon. In that year L. Sohncke [6] made a detailed study of the effect in crystals. All fluorescing, doubly-refracting crystals gave polarized fluorescence. There were cases in which the crystalline material itself did not fluoresce, the radiation coming instead from foreign molecules taken up in an oriented fashion within the crystal. For example, some samples of Iceland spar and topaz fluoresced while other samples of the two minerals did not.

Recently Weinland and France [7] have been concerned with the adsorption of dyes by growing sodium nitrate crystals, and some of their conclusions are as follows:

"The adsorption of the dyes by a growing crystal of sodium nitrate is dependent upon the residual valency force fields of the crystal face; the interionic distances within the crystal face, and the presence and distribution of polar groups in the adsorbed molecule or ion."

"The adsorption is selective for certain faces, namely those having the stronger fields of force."

"The X-ray data indicate that the dye is adsorbed interstitially. If subsequent work proves this to be general, it will account in part at least for the comparatively small number of

substances that are adsorbed by a growing crystal, since, in this event, the adsorbed ions or molecules not only would have to possess the required polar properties to satisfy the adsorptive forces of the growing crystal, but would at the same time have to be of the right dimensions to fit into the interstices of the crystal lattice. The number of substances fulfilling both of these conditions simultaneously would naturally be small."

"One great difficulty which presents itself is that, apparently, there is no simple rule that enables one to predict just what foreign materials will be adsorbed by any one crystalline substance. While comparison of the formulas of those dyes which were adsorbed with those which were not is not especially helpful, such a comparison does, however, show that strongly polar groups are present in all cases where adsorption has occurred. Presumably such groups play an important part in the adsorption process."

Application to Fibres

The above discussion shows the strong foundation of both theory and experiment already laid upon which to build an optical means of investigation or orientation in fibres. Furthermore, it has been known for some time that certain fibres and membranes when dyed exhibit dichroism. Ambronn [8] was the first to observe the phenomenon. In certain cases of leaf membranes stained with iodine, the dichroism was so pronounced that he was able to repeat polarization experiments involving interference colors and retardation plates with the membrane substituted for a Nicol prism. Ambronn immediately perceived the fundamental connection of the phenomenon with the structure of the material, for he writes:

"It is not improbable that interesting conclusions on the fine structure of membranes may be obtained from this effect." The correctness of his foresight will be soon evident.

Although the animal, vegetable and artificial fibres differ considerably in structure, we can gain a good insight into their structural orientation, and methods of measurement, by considering the structure of the cellulose fibres cotton and ramie and its relation to artificial dichroism and polarized fluorescence.

These two fibres are chosen to be illustrative examples because their structure is best known. To give a detailed story of fibre structure as known to date, or even to list the voluminous references, is out of place here. For the reader wishing to survey this field, the three references given under (9) are sufficiently comprehensive.

The principal constituent of the cotton and ramie fibres is cellulose. It exists in the form of a long chain molecule, thus preserving the fibrous characteristics to the smallest division. The chain consists of something like 100 glucose residues ($C_6H_{10}O_5$) linked one to another through an oxygen atom. Various chains do not necessarily contain the same number of these units (do not have the same length) and hence a definite molecular weight cannot be assigned to cellulose. Along its length the chain is held together by primary valence forces, but it is held to other chains lying parallel to it by secondary or residual valence forces, arising principally from the OH groups regularly appearing on the side of the chain. A number of these chains bound side by side constitute a submicroscopic entity called a micelle, and estimated to be some 500 Å long and 50 Å thick. The micelle can be pictured as a bundle of matches, not all of the same length, sticking together because each one has been coated with a little mucilage. If we imagine each match to possess a regularly repeating unit along its length, the analogy would be complete.

The micelle acts as a crystal to X-rays, for there are regularly repeated spacings. The identity period along the chain is 10.3A, which corresponds to two glucose units. Two such units, rather than one, make up the identity period because every alternate one is turned 180°. The other identity periods, perpendicular to the axis, are 8.3A and 7.9A. The unit cell, classified as monoclinic, has for its dimensions $a = 8.3$A, $b = 10.3$A, $c = 7.9$A, angle beta $= 84°$ and contains $4C_6H_{10}O_5$ groups.

Each micelle is a quite perfectly oriented structure; the resultant degree of orientation of the fibre as a whole thus depends upon the degree to which the micelles themselves are aligned parallel to one another. The micelles in ramie are quite well aligned; much more so than in the case of cotton. In the case of rayons it is possible to control the orientation by the amount of

tension on the filament while it is being drawn through the coagulating bath. The micelles in the liquid before it is forced through a small orifice into a coagulating bath are unoriented; in the filament, however, they are partially oriented due to tension and friction at the surface of the filament.[10]

The degree of orientation is an important factor in some of the properties which render the fibre useful to man. For instance, a well oriented fibre is stronger than a poorly oriented one, other factors being equal. So it was a natural development that as the fibre was being studied by X-rays, attention was also given to the information on orientation which could be derived from X-ray studies. If the micelles were completely at random, an X-ray pattern obtained by the scattering of a monochromatic beam of X-rays from a bundle of fibres would be a number of concentric circles (beam perpendicular to photographic plate), typical of a powdered crystal diagram. Actually, however, arcs of circles are observed, the smaller and more intense arcs corresponding to a better oriented structure. This method has until recently been the only one applied to orientation measure, and to it we owe much of the existing orientation knowledge.

Basis of the Present Method

In 1931 Mr. J. M. Preston of Manchester, Eng., published a most important article,[11] describing a method of making quantitative orientation measures based on the dichroism of dyed fibres, and citing numerical values obtained with ramie, viscose rayons and cellophane. His method consists essentially of dyeing the fibre with a direct dye and then obtaining a measure of the absorption of light by the dyed fibre when the plane of polarization is parallel and perpendicular to the fibre axis. A photometer device utilizing a double image and a nicol prism is combined with a microscope in order to obtain the absorption measurements, and these measurements were then interpreted in terms of percentage orientation of the micelles by the formulae

$$\% \text{ orientation} = \frac{D_{11}}{D_{11} + 2D} \times 100 \qquad (1)$$

$$\% \text{ orientation} = \frac{D_{11} - D}{D_{11} + 2D} \times 100 \qquad (2)$$

where D_{11} and D are the measured optical densities when the plane of polarization is parallel and perpendicular to the fibre axis.

A method for orientation measure has been devised in this laboratory based on polarized fluorescence, rather than dichroism, but the same fundamental assumption regarding the interaction of dye and fibre underlies both optical methods, namely: The orientation of the dyestuff molecules on the fibre is dictated by the fibre structure. We are interested in obtaining the micelle alignment, but the quantity actually measured is the dyestuff alignment. When there exists an affinity between fibre and dye, the dyestuff molecule, although not necessarily polar, has within it a group of atoms whose primary valences (attractive forces) are satisfied by each other, but whose electric lines of force do not all arise and end on charges within that group of atoms. Since the OH (and perhaps other) groups of the cellulose chain are similarly constituted, lines of force can exist between the two, holding them together. Since the OH groups have a definite position in the chain, and since it is unlikely that the dyestuff molecule would be symmetrical with regard to its secondary forces, it seems reasonable to assume, especially in view of the results cited in the first part of this report, that a dye molecule is attached to the cellulose chain only in a particular position, or that *the alignment of the dye molecules is a measure of the alignment of the micelles.* The degree to which parts of the dye molecule exert secondary forces, and the degree of anisotropy of the molecule with respect to these secondary forces, varies from one type of molecule to another, as is shown by Lehmann's work. Those dyestuffs with smaller anisotropy and secondary forces will be less oriented, and of a number of dyestuffs on similar samples of like fibres, the one showing the greatest orientation should be taken as most nearly representative of the micelle alignment.

Experiments were first made to determine if cotton or wool fibres could be made to fluoresce with sufficient intensity so that measurements could be made directly on the micelles, avoiding the intermediate step of introducing dye molecules on the fibre to furnish an optical phenomenon. Under strong ultraviolet they fluoresce, but rather weakly. Under good conditions, a cotton fibre could be made visible by its own fluorescence at a magni-

fication of 100, but the introduction of polarization apparatus reduced the intensity below the point where any measurements could be made. The absorption of cotton and cellophane in the ultraviolet was measured on a Hilger quartz spectrograph [12] and found to be very small from the visible 3200 Å, from which point it increased gradually with decreasing wavelength. The lack of an absorption band shows that no strong fluorescence band is to be expected from cellulose. The weak fluorescence is a continuous band extending from 6000 to 4000 Å with a maximum at 4500 Å (figures approximate).

The failure to avoid the use of dyes on the fibre is really a most fortunate occurrence, for in addition to the means afforded for fibre study we are given an excellent means of investigating how the various types of dyestuffs are held on the fibre. For direct dyes, there should be a correlation between fastness to washing and orientation, if our deduction that a poorly oriented dye has weaker secondary forces is correct. A type of dyeing which results in a mechanical inclusion within the fibre of insoluble particles should exhibit but little alignment. With mordant dyes, the orientation should yield information on the linkage of mordant and fibre. There have been attempts to study such problems with X-rays, and the following abstract of this work is quoted from W. A. Sisson's report: [8]

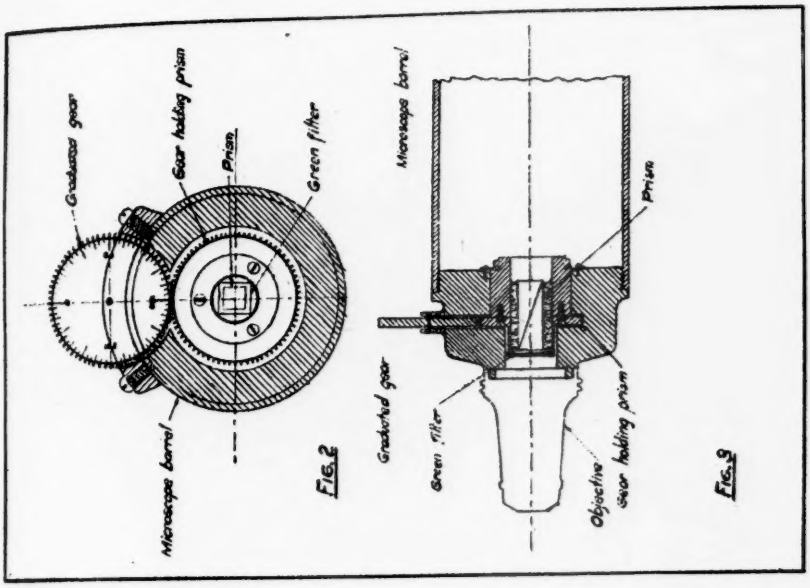
> "Bion [13] attempted to decide by means of X-rays whether the particles of a dye or metal precipitate on a fibre are deposited with a random or preferred orientation, and whether they are combined chemically with the fibre or adsorbed on it. He found that most salts were deposited as unoriented crystals. Organic dyes did not give sharp rings. It is, therefore, most probable that they were adsorbed. From the breadth of the X-ray lines he concluded that coagulation takes place in the process of dyeing. Meyer [14] claimed that the difference in affinity of the various commercial cellulose fibres toward direct dyestuffs was explainable on the basis of the internal structure of the fibres as revealed by X-ray analysis, as well as the shape and dimensions of the dye molecule."

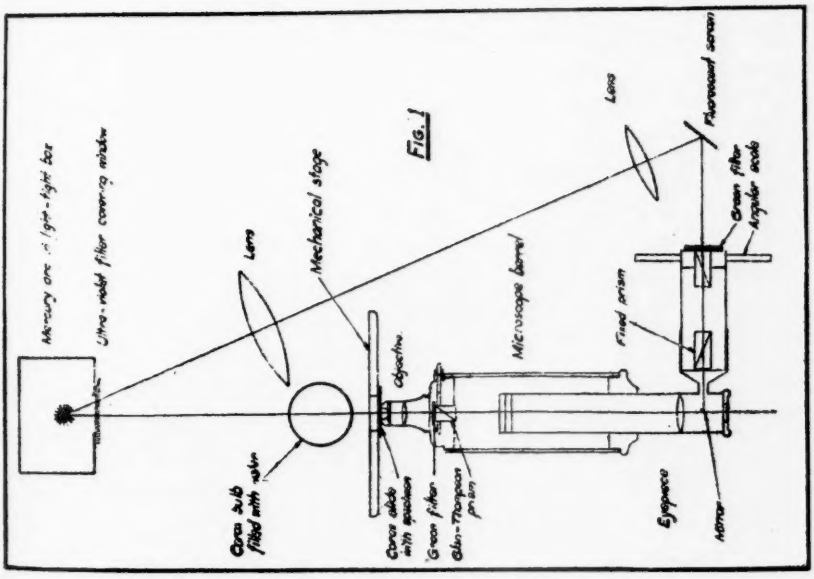
From various considerations it appeared that more precise measurements could be made if the fibre were dyed with a fluorescent dye and percentage polarization measurements made on the fluorescent light; also that such a method could be applied to fibres already containing appreciable natural coloring matter or mordants. Were such fibres dyed and then examined by the dichroic method, the resulting measurements would be unreliable due to the initial absorption being superposed on that of the dye. The polarized fluorescence method has the disadvantage of requiring more special equipment than is found in the usual laboratory.

The Apparatus

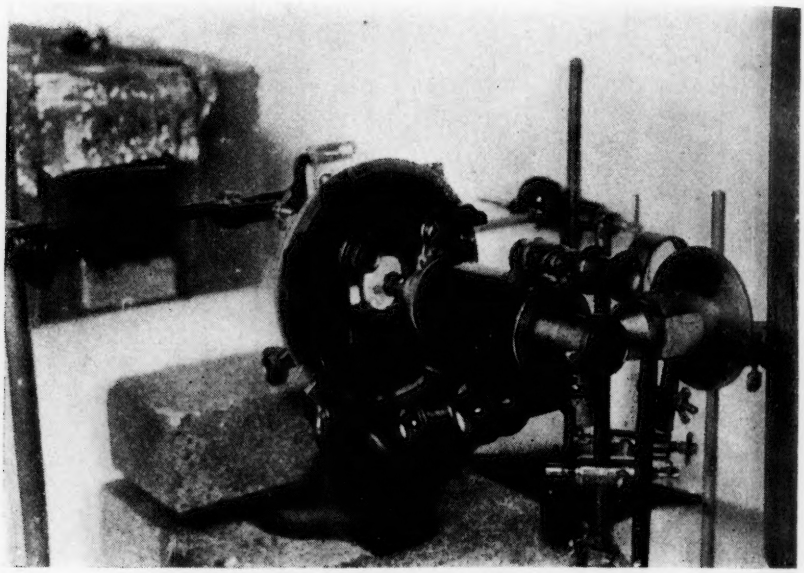
A quartz mercury arc (Fig. 1) serves as the source of ultraviolet, the visible radiation except for the extreme red and violet being filtered out by a 5 mm. thickness of "red purple corex A" glass, made by the Corning Glass Works. This glass is quite transparent (85%), as far as 3000 Å, with the limit of transmission at 2500 Å. The microscope is placed in the horizontal position to dispense with a reflector. The exciting radiation should be unpolarized and as intense as possible. A spherical bulb, 6 cm. in diameter, and made of clear corex A (Corning Glass Works) when filled with distilled water serves quite well as a condensing lens for this work, and costs but a few cents, whereas a quartz condenser costs $25 or more.

The specimen is mounted on a corex slide (as good as quartz for this purpose and much less expensive) or on a special device to be described later, and the ultraviolet is focussed on the specimen by means of the corex bulb condenser. The specimen is made visible by the fluorescent light arising from the dye molecules in it. Behind the objective (or before it, if a long, focal-length objective is used) a piece of plane-parallel green glass is placed, to filter out the red and violet which are transmitted by the filter in front of the mercury arc. The two filters, if placed together, transmit no visible radiation. The second transmits the fluorescent light, from yellow to blue, which arises on the fibre, and filters out the unwanted radiation. Such filters, much used


Graduated gear
Gear holding prism
Prism
Green filter
Microscope barrel
Fig. 2
Microscope barrel
Prism
Graduated gear
Green filter
Objective
Gear holding prism
Fig. 3


Mercury arc in light-tight box
Ultra-violet filter covering window
Lens
Mechanical stage
Fig. 1
Lens
Fluorescent screen
Quartz slide with specimen
Green filter
Glan-Thompson prism
Microscope barrel
Fixed prism
Green filter
Angular scale
Eyepiece
Mirror

in fluorescence work, are called Stokes filters, after Sir George Stokes, pioneer in fluorescence.



SIDE VIEW OF APPARATUS

The objective is held in a special mounting (Figs. 2 and 3) which also carries a Glan-Thompson prism (end faces perpendicular to the path of light, which is not the case for a Nicol prism). The mounting is so devised that the prism can be rotated, and the rotation measured. This mounting, and the eyepiece mounting, were so made that they are interchangeable with the pieces which screw on the ends of the body tube of an ordinary non-polarizing microscope, equipped with a mechanical stage. No permanent change of the microscope is necessary to adapt it to this problem; it is necessary only to remove the condenser and mirror, and the ends carrying objective and eyepiece. The tooth wheel on the outside engages a similar wheel screwed on the brass piece which carries the prism. The outside wheel has an angular scale which is read through a short focus telescope with cross hair, mounted on the body tube with hard paraffin.

Method of Measurement

An alignment of the dyestuff molecules manifests itself in a partial polarization of the fluorescence. The measurement of the percentage polarization is accomplished by measuring the intensity of light coming from some area on the fibre for certain positions of the analyzing prism. To measure these intensities an eyepiece is used which carries in it a blackened needle on a device permitting the point of the needle to be placed in the focal plane of the eye lens. On the point of the needle there is mounted a tiny mirror, not over 0.5 mm.[2] Such a mirror may be obtained by carefully scraping from the back of a glass mirror some of the reflecting surface. With good fortune, some little pieces will separate cleanly from the glass and retain a plane surface, and one can be placed on the end of the needle (which has been slightly flattened) with a trace of dilute glue.

The mirror receives light through a hole in the side of the eyepiece and reflects it to the eye. The source of this comparison light is a strip of cardboard painted with fluorescent paints, and receiving ultraviolet from the same arc which radiates the fibre. Hence, the fluctuation of the arc does not lessen the accuracy of the intensity measurements. In passing from the fluorescent screen to the mirror within the eyepiece, the comparison light passes through two polarizing prisms in series; the one nearest the cardboard being free to turn in a graduated holder. In order that the color of the comparison light may match that of the fluorescence from the fibre, the paints on the cardboard are put on so that there is a gradual transition from red to blue, and by placing different portions of the strip in the ultraviolet, any desired band of color may be obtained.

The procedure is to superpose, by means of the mechanical stage, the image of the mirror on that part of the fibre image whose orientation is desired, and then with the train of prisms vary the intensity of the mirror image until it blends into the fibre image. The intensity of this comparison light (I) is obtained from the relation

$$I = I_0 \sin^2 \theta$$

where I_0 is the intensity of the comparison light when the prisms are set for maximum transmission, and θ is the angle between the positions of the moveable prism for extinction and for equal intensities of fibre and mirror images. In this work, a 4 mm. (44×) objective and a 10× eyepiece have been most satisfactory.

Other forms of photometers combined with the microscope are those in which the comparison source is a second image of the object, produced by a double image prism. Königsberger's microphotometer [15] is the first of this type. In the comparison microscope, two separate objects are viewed with two objectives, and the two images are brought side by side into one eyepiece by reflecting prisms. This type of device can be used as a microphotometer by providing some quantitative means of varying the intensity of one image. Conklin [16] describes the use of a wedge of varying opacity. Devices which measure the image intensity by means of a photocell are unsuitable for this work because of the unsteadiness of the mercury arc. For this work, the device of the mirror within the eyepiece seemed best suited.

Measurement of Degree of Orientation

So far, we have discussed orientation of the micelles and dye molecules, and have said that an alignment will result in partially polarized fluorescence. We must now define "degree of orientation" or "alignment" in terms of the physical quantities which are a result of such alignment and which we are able to measure. If the intensity of light emitted from any one dye molecule is i, and if the oscillator path (assume it linear) makes an angle α_m with the vibration-transmitting direction of the analyzing prism, the observable intensity I is:

$$(i \cos^2 \alpha_1 + i \cos^2 \alpha_2 + i \cos^2 \alpha_3 + \cdots i \cos^2 \alpha_m + \cdots i \cos^2 \alpha_n)$$

thus adding the effects of all the molecules per unit area per unit time which radiate. The sum of all these terms, each of which represents the contribution of one molecule, may be represented as $ni \cos^2 \alpha$, where n is the total number of molecules per unit area per unit time which radiate, and α is a sort of average

angle of all the angles α_1 to α_n. Similarly, if the prism is turned 90° to the first position, the observable intensity is $ni \cos^2 \beta$, where β is a sort of average angle the molecules make with the new direction of the prism. In a direction perdendicular to these first two, the intensity would be $ni \cos^2 \gamma$, and

$$\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = 1$$

Hence the sum of the intensities measured in any three mutually perpendicular directions is a constant.

To test for alignment, the intensity of fluorescence from the fibre as it lies in the plane of the microscope stage is measured for various positions of the prism, and also for various positions of the fibre as it is turned about its axis. This is made possible by mounting the fibre in air between two points, so arranged that they can be rotated together. The device is held on the stage as though it were a slide, and permits the fibre to be rotated about an axis perpendicular to the axis of the microscope. In general, the alignment in fibres is parallel to the axis, but the ability to rotate the fibre enables one to determine the direction when such is not the case. The position of the analyzing prism for which the fluorescent intensity is a maximum gives the direction of maximum orientation. Let us call this the X direction, and the intensity $I_x = ni \cos^2 \alpha$. Thus α gives a measure of the parallelism of the dye molecules to the X axis. Now imagine a section of the fibre cut perpendicular to this experimentally found X axis. This section contains the Y and Z axes, and we will arbitrarily say that the Y axis coincides with the direction of maximum orientation in the YZ plane, the Z axis thus falling in the direction of least orientation. Then the intensity observed when the vibration transmitting direction of the prism is parallel to Y is

$$I_y = ni \cos^2 \beta, \text{ and similarly, } I_z = ni \cos^2 \gamma$$

It may be that there is no alignment of the particles as observed by their components in the YZ plane; in such case $I_y = I_z$. If there is no alignment at all, then $I_x = I_y = I_z$. An alignment is indicated by a difference between two of these quantities, thus $I_x - I_y$ or $I_x - I_z$, and to obtain an orientation measure

independent of the absolute magnitudes of the intensities, the differences are divided by the quantity $(I_x + I_y + I_z)$ whose value is independent of the orientation. If we multiply by 100, we have an expression which measures orientation, on the very convenient scale of 0 — 100, 0 representing random orientation and 100 representing perfect alignment. Thus we have:

$$\frac{I_x - I_y}{I_x + I_y + I_z} \times 100 \text{ and } \frac{I_x - I_z}{I_x + I_y + I_z} \times 100$$

Both expressions are necessary to completely specify the state of orientation. With the prism turned so as to transmit vibrations in the X direction, I_x is measured. Then upon turning the prism 90°, some intensity (not necessarily I_y or I_z) is measured. By making a number of readings of I_x and the intensity at 90°, for different positions of the fibre, as it is turned about its axis, a position will be found where the ratio of I_x to the intensity at 90° to I_x is a minimum. At this position the intensity at 90° to I_x is I_y. Where the ratio is a maximum, it is the ratio I_x/I_z. The values I_x, I_y, I_z thus obtained are not yet the ones to be substituted in the above expressions. I_x and I_y are measured together on a certain group of molecules, but I_x and I_z are measured on a different group of molecules (the fibre having been turned) whose density is probably different from that of the group on which I_x and I_y were measured. Therefore the values of I_x will be different in the two cases, due not to any difference in orientation, but merely to a change in the number of molecules per unit area per unit time emitting light. The values of I_x and I_z must then both be multiplied by some factor which brings the value of I_x to that value it had when measured with I_y. This new value of I_z is the one to be used with the values of I_x and I_y and all three put in the above expressions.

The above is a rigorous derivation, giving an accurate orientation measure for all conditions. Fortunately, in many cases there are simplifying conditions which render the task much less involved. When there is no orientation in the plane perpendicular to X, $I_y = I_z$, and the orientation is given by the expression

$$\frac{I_x - I_y}{I_x + 2I_y} \times 100$$

When, in addition, it is known that for the material under test the alignment is parallel or nearly parallel to the fibre axis, there is no need for a rotation of the fibre. It can then be simply mounted on a corex slide, in air, with a cover glass to hold it. All the measurements needed are two: with the prism parallel and perpendicular to the fibre axis. This simplified procedure will in most cases give reasonably accurate results, and the use of the rigorous method should be an exception rather than the rule.

The derivation of the rigorous expressions is of value in showing that an optical measure of orientation is basically a summation of components in a certain direction.

The relation within the dye molecule of the optical mechanism and the anisotropic feature enabling the dye molecule to be aligned by external fields (that is, their relation in space to each other) is an interesting question, and has an important bearing on the interpretation of results obtained from this method. If they are either parallel or perpendicular, the maximum component of the polarized fluorescence will be parallel or perpendicular to the micelle alignment. That is, there may be cases in which I_x is found perpendicular to the fibre axis, instead of parallel; in either case, however, one would assume the alignment of micelles to be parallel to the fibre axis. But, it is not impossible that the optical and attractive mechanisms for certain dyes operate in planes other than 0° or 90° to each other. In such cases, the maximum orientation as judged from the maximum component of fluorescence would lie at a different angle to the fibre axis than the true micelle orientation, and would give the false impression of a spiralling structure. So before drawing conclusions on the direction of micelle orientation, several dyes should be used. An X-ray diffraction pattern can provide independent information on this point.

Correlation with X-ray Analysis

That an optical method can be devised to measure orientation does not mean that the X-ray method should not be used as much as it has been in the past; rather, a cooperative use of the two should be made, for each has its strong and weak features which

can be supplemented by the other. Thus, the X-ray method alone is possible for materials incapable of being dyed, or opaque to light. It can give a measure of the average or integrated orientation of a number of fibres, or of matter in bulk. The optical method is capable of more quantitative measures, and can measure the orientation of various portions of a single fibre. It can also give information on the arrangement of dye particles, which, because of their relative scarceness and irregular spacings from one to another, yield no information to X-ray methods. The orientation is found to vary even on a single fibre, and, for this reason, it is necessary to average a number of readings to obtain consistent results.

After the development of method and apparatus, experimental work was done to see if results obtained with this optical method agreed with the results already known from X-ray work and Preston's work. Substantial agreement with the already known facts was obtained, and it is, therefore, my opinion that results obtained on unknown materials may be accepted as trustworthy. I have given the background and the fundamental facts and assumptions which underlie this method, for such are essential to a correct interpretation and understanding of any results obtained therefrom. I will welcome any discussion and criticisms. Various projects are under way, but no final results are yet at hand. New experimental data and conclusions will be presented in a later report.

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The Mercerization of Cotton for Strength*

By J. B. WILKIE†

Introduction

THE process of mercerization is named after John Mercer, who, in 1850, obtained a patent, one claim of which is that cotton fibres and cloth are strengthened by treatment with caustic soda or certain other substances. Another patent granted in 1890 to Arthur Lowe points out that the luster of cotton textiles is improved by mercerizing them under tension. From the time of Lowe's patent to the present the primary object of commercial mercerization has been either to improve the appearance of yarns and fabrics by increasing their luster or to improve their dyeing qualities. However, there is a growing demand for cloth of the greatest strength for a given weight, especially for use in aviation. Hence the possibility, first pointed out by Mercer, of increasing the strength of yarn and cloth by mercerization is now of greater importance than at any previous time.

The literature indicates that the strength of cotton yarn or cloth can be materially increased by mercerization, but the conditions for obtaining the maximum increase in strength have not been worked out systematically.

The purpose of the study to be described was to determine the conditions for mercerizing cotton yarn to obtain the maximum strength for a given weight. Apparatus for controlling the variables was built and yarns were mercerized with it under systematically varied conditions of tension, time, temperature and concentration of caustic soda. Attention was given to the relation between the count, twist, and ply of yarns and the increase in strength resulting from mercerization.

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The experiments were limited to yarn mercerization because of the better control that appeared to be possible. However, the results obtained should be applicable to the mercerization of cloth as well as yarn.

Summary

The mercerization of cotton yarn was studied at the request and with the financial assistance of the National Advisory Committee for Aeronautics. The object was to determine the conditions for the production of yarn having the maximum strength for a given weight. Experiments were conducted under strictly controlled conditions varying the tension on the yarn, time and temperature of mercerization, and concentration of caustic soda. Yarns varying from count 10 to 90, some of them in a series of twists, were mercerized.

The removal of all extraneous materials from the yarns by means of a thorough pretreatment was found to materially increase its strength. A further increase resulted when pretreated yarn having low twist, obtained with twist multipliers from 2.2 to 3.0, was mercerized. The maximum increase was obtained when sufficient tension was applied to the yarn in the caustic bath to prevent it from contracting more than 2 or 3 per cent, mercerizing at a temperature of 0° C. or lower, with a caustic soda solution having a concentration of 10 per cent or higher, for 5 minutes.

The results clearly indicate that the twist in the yarn must be low if the maximum increase in strength is to be obtained. The strength of such yarns can be increased from 40 per cent to 100 per cent over that of the original yarn of the same weight.

Materials and Equipment

Cotton yarn of count 80 spun from 1 5/16 inch staple length good middling Peeler cotton in the Bureau cotton mill was used for the study of the variables of the mercerization procedure. This yarn was spun with twist multiplier 3 [1] giving about 27 turns per inch, slightly lower twist than is required to produce grey yarn of maximum strength. Yarns of count 80 made from

TABLE 1

Results for the mercerization of yarns of different counts and twists. Caustic soda concentration 10%; temperature −10° C.; time 5 min.; tension as indicated. The 10's and 20's yarn were made from 1 in., the 35's from $1\frac{1}{16}$ in., and the other yarns from $1\frac{5}{16}$ in. staple length Peeler cotton, unless otherwise indicated.

			Actual Count						Nominal strength in lbs. per 100 ends	
					Mercerized					
Nominal count	Twist multiplier	Ply twist in turns per inch	Grey	Pretreated	Load during mercerization in lbs. per 100 ends			Double mercerization	Grey	Pretreated
					0.2	1.1	other			
90	2.6		84	94	87	94			18	22
80	2.0		78	87	80	84			16	21
80	2.2		80	83	81	85		77	17	24
80	2.5		77	78	69	79			20	26
80	3.0		78	85	73	86			21	25
80	3.5		74	78	72	78			22	25
80	5.0		76	79	75	82			20	22
80	6.7		70	82	81	79			13	15
60–2			79	83	76	80			22	26
60	2.8		58	61	53		59 [c]		32	35
60 [b]	3.7		61	67	56		62 [c]		37	45
40	2.4		41	43	39	44	45 [e]	41	46	57
40	4.0		40	42	40	42	42 [d]		48	52
40	4.2		42	41	38		46 [d]		58	63
80–2	2.5	10	38	42	36	43		38	39	59
80–2	2.8	18	40	46	40	44			53	63
80–2	2.9	30	36	38	36	38	41 [e]		59	63
80–2	3.5	10	37	41	37	39	42 [e]		52	63
80–2	5.0	25	39	41	37	42	43 [e]		56	57
80–2	6.4	40	40	41	39		43 [e]		44	50
35	2.5		35	35	32		36 [f]	32	23	43
35	3.3		32	37	32		36 [f]		39	57
35	4.5		34	35	33		37 [f]		46	48
20 [d]	2.5		20	22	19	21 [e]	19 [g]	21	38	76
20	3.5		20	20	19		23 [e]		78	94
20	4.7		20	20	19		21 [e]		88	78
10	2.5		9.7	10.0	8.5	10.3 [i]	9.5 [i]	10	114	184
10	4.1		9.7	10.5	9.2		10.2 [h]		163	170
10	5.1		9.7	10.8	10.1		11.0		174	155

[a] Staple length and kind of cotton not known.
[b] Pima cotton.
[c] Load during mercerization 1.5 lbs. per 100 ends.
[d] " " " 2.25 " " " " "
[e] " " " 4.5 " " " " "

TABLE 1, *Continued.*

Nominal count	Twist multiplier	Ply twist in turns per inch	Nominal strength in lbs. per 100 ends: Mercerized, Load during mercerization in lbs. per 100 ends: 0.2	1.1	other	Nominal strength in lbs. per 100 ends: Double mercerization	Nominal strength in lbs. per 100 ends: Pretreated	Increase in strength over that of grey yarn in %: Mercerized, Load during mercerization in lbs. per 100 ends: 0.2	1.1	other	Increase in strength over that of grey yarn in %: Double mercerization
90	2.6		21	25			22	17	39		
80	2.0		27	30			31	69	88		
80	2.2		27	31		29	41	59	82		71
80	2.5		21	31			30	5	55		
80	3.0		23	30			19	10	43		
80	3.5		23	27			14	5	23		
80	5.0		20	23			10	0	15		
80	6.7		16	16			15	23	23		
60–2			33	33		32	18	50	50		45
60	2.8		33		40 [c]		9	3		25 [c]	
60 [b]	3.7		34		42 [c]		21	−8		14 [c]	
40	2.4		65	68	74 [e]	69	24	41	48	61 [e]	47
40	4.0		54	57	54 [d]		8	12	19	12 [d]	
40	4.2		47		63 [d]		9	−19		9 [d]	
80–2	2.5	10	68	81		75	51	72	108		92
80–2	2.8	18	70	76			19	32	43		
80–2	2.9	30	66	70	76 [e]		7	12	19	29 [e]	
80–2	3.5	10	66	75	77 [e]		21	27	44	48 [e]	
80–2	5.0	25	63	67	71 [e]		2	12	20	27 [e]	
80–2	6.4	40	50		59 [e]		14	14		34 [e]	
35	2.5		54		58 [f]	54	87	135		152 [f]	135
35	3.3		53		61 [f]		46	36		56 [f]	
35	4.5		49		54 [f]		4	7		17 [f]	
20 [d]	2.5		97	103 [e]	105 [g]	111	100	155	171 [e]	176 [g]	192
20	3.5		102		116 [e]		20	31		49 [e]	
20	4.7		88		89 [e]		−11	0		1 [e]	
10	2.5		240	245 [h]	245 [i]	242	61	135	114 [h]	115 [i]	112
10	4.1		172		188 [h]		4	5		15	
10	5.1		165		180 [h]		−11	−5		3 [h]	

[f] Load during mercerization 2.6 lbs. per 100 ends.
[g] " " " 0.2 " during rinse 4.5 lbs. per 100 ends.
[h] " " " 9 " per 100 ends.
[i] " " " 0.2 " during rinse 9 lbs. per 100 ends.

the same cotton in other twists were used in studying the effect of twist. Information concerning certain other yarns used for the experiments is given in the title to Table 1.

Commercial caustic soda was purified for these experiments by allowing a 48.5 per cent stock solution to settle, the clear supernatant liquor being used. After this purification, the solution contained 0.001 per cent iron [2] and 0.5 per cent anhydrous sodium carbonate. This concentrated solution was stored in pyrex glass bottles which were equipped with ascarite tubes to prevent contamination from atmospheric carbon dioxide. It was diluted with carbon dioxide free distilled water for use in the experiments.

The apparatus which was designed for the mercerization of the yarns is shown in Fig. 1. It consists of a constant temperature bath in which the containers for the solutions used can be placed and a mechanism for the support of the yarn which provides for the measurement and control of the tension on it. The mechanism is suspended as a unit by cables which pass over pulleys on the cross-tree at the top of the mast shown in the center of the figure to weights which serve as counter-poises. The mechanism can be lowered to bring the yarn into the solution below it. The mast can be rotated to bring the mechanism over any one of the three containers.

The bath is equipped with motor driven agitators and is filled with water or, for low temperatures, with alcohol. It is provided with a coil through which either steam or cold brine can be circulated. An auxiliary electric heating unit controlled by a thermostat supplements hand control and permits the temperature to be held constant to within 0.5° for any temperature between about 96° C. and —10° C. Three openings in the top of the bath (covered in the photograph) accommodate monel metal containers of 15 liters capacity in which the caustic soda solution and rinse waters are placed.

The frames on which the yarn to be mercerized is wound and the winder are shown in Fig. 2. The holes in the corners of the frames slip over studs on the supporting mechanism just above the bath in Fig. 1 in which the six frames that are accommodated at one time are shown in place. The ends of the frames are held apart by detachable links (Fig. 2) that are removed when the

frames are placed on the studs (Fig. 1). The lower studs are fixed. The upper studs are attached to a carriage that is free to move vertically on guide rods. The carriage is suspended by a cable from the spring scale which is attached above to a rack that is in turn suspended by a cable passing over pulleys and terminating in the bag of shot (A) in Fig. 1. There is too much friction in this mechanism to permit the bag of shot to be used

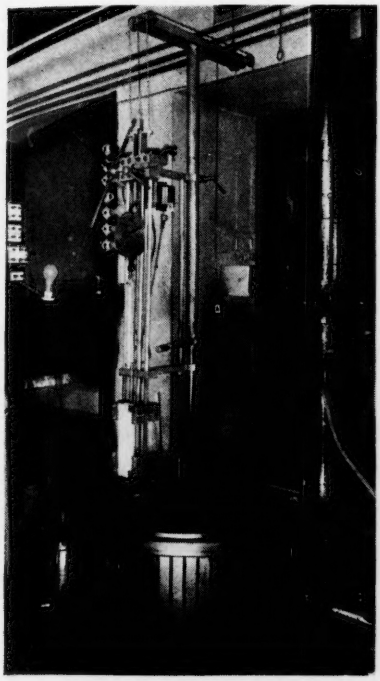

FIG. 1. Machine for mercerization of yarns in the laboratory.

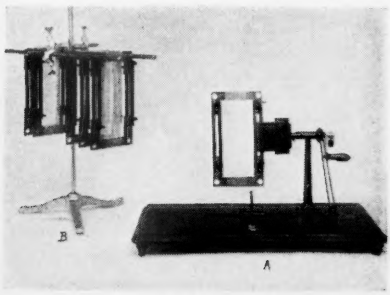

FIG. 2. Method of winding yarn on frames for mercerization.

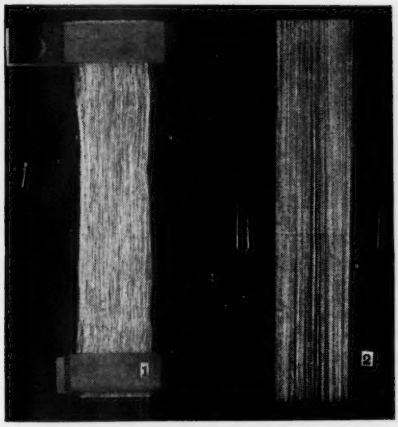

FIG. 3. Mercerized yarn after transfer from the metal frames, 1 for strength tests, 2 for determination of count.

as a constant known load on the yarn. It is simply used as a counterpoise. The load on the yarn is obtained by hand operated pinion gears which engage the rack. The load on the yarn is indicated by the pointer on the spring scale. Another pointer,

attached to the cable from the carriage to the scale, indicates on a ruler any changes in length of the yarn during processing. A propeller directly below the yarn driven by a small motor (B in Fig. 1) keeps the liquid in which the yarns are placed thoroughly agitated.[3]

The apparatus used in preparing the yarn for mercerization is described in the next section.

Procedure

1. *Pretreatment*

All of the yarn used in the experiments was given the pretreatment now to be described. The purpose of the pretreatment was to remove cotton waxes, oils, and in fact all extraneous materials in order to prevent contamination of the mercerizing solution and to provide a uniform material for mercerization. A commercial pretreatment was not given because foreign materials usually are not completely removed by such treatment. The procedure followed is similar to that recommended by Corey and Gray for the preparation of standard cellulose.[4] The grey yarn in the form of 3000 yard skeins was extracted for 14 hours with ethyl alcohol, then for 14 hours with ethyl ether. Finally, it was boiled for 6 hours with a 1 per cent aqueous solution of caustic soda. The extraction apparatus was constructed from an aluminum pressure cooker and functioned like an ordinary Soxhlet extractor. The yarn was placed in a glass container, contact with metal being avoided. The caustic soda boil was carried out in a monel metal can provided with an agitator. The yarn was kept submerged and was protected from mechanical action by placing it in a cheese cloth net. The alpha cellulose content of the pretreated cotton was 99.7%.

2. *Mercerization*

The pretreated yarn to be mercerized was conditioned by exposure for at least 24 hours in an atmosphere of 65 per cent relative humidity having a temperature of 70° F. One hundred turns, about 56 yards, were then wound upon each frame with the winder shown at A in Fig. 2, a very small but uniform tension being applied during winding. The frames were next placed

in position on the apparatus that has been described. After the first frame was placed on the apparatus, the movable carriage was locked in position. The connecting links of the frame were next removed. The remaining five frames were placed in position in like manner, each having its connecting links removed. The carriage was then unlocked and the desired tension was applied to the yarn. This tension was maintained during mercerization, or changed as desired, by the hand operated rack and pinion. The mechanism was then lowered to immerse the yarn in the caustic soda solution. After the caustic treatment was completed, the yarn was shifted over into another container filled with distilled water at a temperature of 0° C., or, if mercerization was carried out at room temperature or higher, 20° C. This rinse was followed by three 5-minute rinses with tap water. Any caustic remaining in the yarn was then neutralized by placing the yarn for 10 minutes in a 1 per cent solution of acetic acid at room temperature. The yarn was then given three 5-minute rinses with tap water, followed by a final 5-minute rinse with distilled water, all at room temperature. The mercerized yarn was then removed from the final rinse by elevating the mechanism. The tension was reduced to about 0.2 pound per 100 ends and the yarn was allowed to dry in a current of air from an electric fan.

When the yarn was dry, it was shifted from the metal frames to cardboard holders, care being taken not to disarrange it. Yarn to be used for the breaking strength test was obtained as shown at 1 in Fig. 3. Gummed paper was pasted over the yarn to hold it to the cardboard. The yarn was then cut across at each end where it looped back, giving two sheets of strands. Yarn to be reeled and weighed for the determination of count was obtained as shown at 2 in Fig. 3.

3. *Testing*

All tests were made after conditioning the yarn by exposure for at least 24 hours in an atmosphere of 65 per cent relative humidity having a temperature of 70° F.

The count of the yarn, *i.e.*, the number of 840 yard lengths in a pound, was obtained by calculation from the weight of a 45 yard length.

The breaking strength of the yarn was found as follows: The one hundred strands taken from one side of the frame as described above were inserted simultaneously (multiple strand method) in the jaws of a pendulum type tester. The capacity of the machine was 110 pounds except for testing the 10's yarn, when a machine of 300 pounds capacity was used. The distance

TABLE 2

Effect of pretreatment and mercerization on diameter of yarn mercerized with a 10% solution of caustic soda; temperature −10° C.; time 5 minutes.

Nominal count*	Twist multiplier of yarn	Diameter in millimeters			
		Grey	Pretreated	Mercerized	
				Load during mercerization in lbs.	
				0.2	1.1
80	2.0	0.134	0.135	0.100	0.094
80	2.2	.129	.124	.102	.086
80	2.5	.136	.134	.116	.110
80	3.0	.124	.132	.098	.091
80	3.5	.113	.121	.110	.093
80	5.0	.100	.105	.099	.092
80	6.7	.106	.112	.093	.102
40	2.4	.157	.163	.132	.130
40	4.0	.164	——	.151	.132
35	2.5	.200	.170	.143	.142
35	4.5	.148	.148	.146	.131
10	2.5	.435	.364	.343	.271
10	4.1	.318	.318	.309	.269

* For actual count and nominal strength see Table 1.

between the jaws was four inches and the rate of separation was 12 inches per minute. The elongation of the yarn at break was recorded by the machine. Six breaks were made for each mercerization and the results averaged.

Pretreatment or mercerization affects not only the strength but also the count of a yarn. Since the strength of a yarn is very nearly proportional to the reciprocal of the count for small changes in count, the strength of each yarn was multiplied by

the ratio of its actual count to the nominal count of the grey yarn (given in the first column of Table 1). The nominal strength thus obtained, that is, the (approximate) strength the yarn would have had if its count were the nominal count of the grey yarn, is a useful figure for comparison of the results of the treatments. It is the figure reported in this paper.

Results

1. *Pretreatment*

Scouring, kier-boiling, bleaching or other wet treatments that may precede the mercerization of cotton yarn remove non-cellulosic materials and decrease the weight. At the same time the yarn may shrink or stretch. The very thorough pretreatment given the yarns used in this study resulted in changes in the nominal strength of from — 11 per cent to 100 per cent of that of the grey yarn depending upon the size, twist, ply and character of the yarn. In general, the low twist yarns showed the greater increase in strength. Data for a variety of yarns are given in Table 1.

The pretreatment also resulted in an increase in the diameter of the yarn, a fact of significance for aeronautical uses, for example in cotton parachute cloth, where the air permeability of the cloth must be controlled. The diameters of some of the yarns before and after pretreatment and mercerization are given in Table 2.

2. *Tension*

In order to determine the relation between the tension applied during mercerization and the strength of the resulting yarns, experiments were run in which the tension was varied and the other conditions were those reported to give the maximum swelling and optimum commercial result.[5] The caustic soda concentration was 23 per cent, the mercerization temperature was 20° C and the time of immersion in the caustic five minutes. Three tensions were applied: 0.2 pound per 100 ends, which was the tension just necessary to eliminate the slack in the yarn, 1.1

pounds per 100 ends, and 2.8 pounds per 100 ends. In some experiments, the tension was applied to the yarn just before it was placed in the caustic soda bath and was not removed until after the final rinse. In others different tensions were used during immersion in the caustic and in the rinses.

TABLE 3

Effect of tension on the strength and elongation of 80's yarn (Twist multiplier 3) mercerized with a 23% solution of caustic soda for 5 minutes at 20° C. Data for the grey and pretreated yarns are given for comparison.

(Loads given are per 100 ends of yarn)	Actual count	Nominal strength	Increase in strength over that of grey yarn in %	Elongation at break in %	Maximum contraction in mercerization bath in %*	Contraction at end of final rinse in %*
Grey yarn	78	21	—	6	—	—
Pretreated yarn	85	25	19	5	—	—
0.2 lb. in mercerization and rinses	73	21	0	10	15	11
1.1 lbs. in mercerization and rinses	83	25	19	2	0	−2
2.8 lbs. in mercerization and rinses	83	25	19	1	—	—
0.2 lb. in caustic and 1.1 lbs. in rinses	80	23	10	4	10	5
0.2 lb. in caustic and 2.8 lbs. in rinses	79	22	5	2	12	4

* Based on length of yarn before entering caustic solution.

The results are given in Table 3. The strength of the pretreated yarn was not improved by mercerization. It was in fact decreased where the tension was only 0.2 pound. Later experiments were carried out under the conditions subsequently found to be more favorable to an increase in strength with yarns differing in size and construction. The results, which are given in Table 1, indicate that in general a tension greater than enough to eliminate slack is required for an increase in nominal strength over that of the pretreated yarn. Further, they show that, provided sufficient tension is applied, a considerable variation in the tension does not materially affect the results.

The last two experiments in Table 3 show the effect of applying tension to the yarn in the rinse instead of during immersion in the caustic. They indicate that tension should be applied in the caustic bath.

The amount of contraction of the yarn in the caustic solution was observed. It was dependent upon the tension applied during mercerization. All of the yarns studied except those having relatively high twist contracted between 10 and 16 per cent when only 0.2 pound tension was applied to the yarn in the caustic solution. With the greater tensions tried, they contracted not over 3 per cent and some of them stretched 1 or 2 per cent. The yarns which contracted in the caustic all elongated somewhat during the rinsing.

The practical result of the contraction was the effect on the elongation of the mercerized yarn. The elongation at break of yarns mercerized under conditions permitting them to contract was equal to, or several per cent higher than, that of the grey or pretreated yarn whose elongation varied from 4 to 7 per cent (rarely 10 per cent). The elongation of the yarn mercerized under a tension of 1.1 pounds or more was usually from 2 to 5 per cent.

3. *Time*

A series of experiments was performed in which the time of immersion in the caustic was varied from 30 seconds to one hour. A tension of 1.1 pounds per 100 ends and a 23 per cent solution of caustic soda were used in these experiments. The nominal strength of the resulting yarn remained practically unchanged as also did the elongation at the break. This indicates that for periods over 30 seconds the time of immersion under the specified conditions does not affect the strength of the yarn.

4. *Temperature*

The 80's yarn, twist multiplier 3, was mercerized under different conditions of temperature and concentration of caustic, the time of mercerization being 5 minutes and the load 1.1 pounds per 100 ends. The results are given in Table 4. The nominal strength of the yarn mercerized at 0 and — 10° C was somewhat higher than that of the pretreated yarn (nominal strength 25 pounds per 100 ends). Temperature appears to have little effect in the range 10° to 96° C.

5. *Concentration of Caustic*

Table 4 also gives the results of mercerization experiments covering a range of concentrations of caustic from 5 per cent to 48 per cent. There is no clear evidence that the nominal strength is materially influenced by variations in the concentration within this range. It was not possible to run an experiment with a 5 per cent solution of caustic at — 10° C. because of the separation of a crystalline hydrate.

TABLE 4

Relation between temperature and concentration of caustic solution and the nominal strength of 80's yarn (Twist multiplier 3) when it was mercerized for 5 minutes under a load of 1.1 lbs. per 100 ends.

The values given are the nominal strength in pounds per 100 ends.

Temperature in degrees Centigrade	Concentration of NaOH in %.						
	5	6	10	15	23	36	48
96	25		26	26		25	
95					24		
75					23		
50	26		25	26	25	24	
30					25		
20		25	25	26	25	26	26
10					27		26
0		26			28	26	
−10			30	29	28		

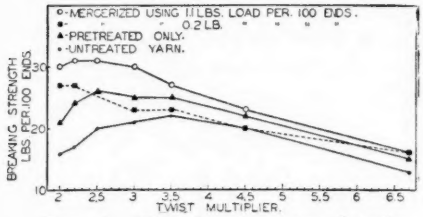
MERCERIZED USING 1.1 LBS. LOAD PER. 100 ENDS.
" 0.2 LB. " " " "
PRETREATED ONLY.
UNTREATED YARN.
BREAKING STRENGTH LBS PER.100 ENDS.
TWIST MULTIPLIER.

FIG. 4. Relation between breaking strength and twist 80's cotton yarn.

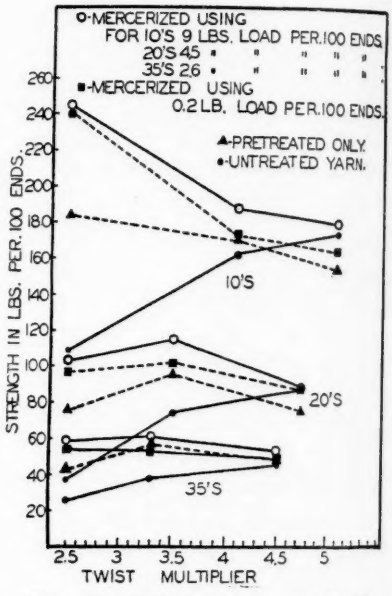

FIG. 5. Relation between breaking strength and twist 10's, 20's, and 35's cotton yarn.

6. *Twist*

The results of the experiments already described led to the selection of the following conditions for a study of relation of yarn twist to mercerization for strength: tension 1.1 pounds per 100 ends for 80's, time 5 minutes, temperature — 10° C., caustic

concentration 10 per cent. A series of 80's yarns spun from the same cotton with twist multipliers ranging from 2 to 6.7 was mercerized under these conditions. Yarns of other counts, some of them in several twists, were mercerized under the same conditions except that the tension applied to the stronger yarns was greater. The results are given in Table 1. Some of them are presented graphically in Figs. 4 and 5. The pretreatment of the grey yarn increased the strength of the yarns of twist multipliers up to 3.0 much more than that of the higher twist multipliers. In some cases it actually weakened the yarns having higher twists. Mercerization under a tension of only 0.2 pound per 100 ends usually increased the strength of low twist yarns over that of the pretreated. In some cases it decreased the strength of the higher twist yarns. In every instance when a greater tension was applied, mercerization resulted in yarn having greater nominal strength than either the grey yarn or the pretreated yarn. The maximum increase over the strength of the grey yarns was in excess of 150 per cent for the low twist, low count yarns and 80 per cent for the low twist 80's.

Two-ply 160's and two-ply 80's yarn were mercerized with results similar to those obtained with singles of the equivalent count.

7. Double Mercerization

From the results given above it appeared that a tension greater than 0.2 pound per 100 ends applied while the yarn is in the caustic solution is essential for the maximum increase in strength. The elongation at break of yarn so mercerized is very low, usually about 2.5 per cent and practically never exceeding 5 per cent. Yarn with too little stretch is undesirable for many purposes.

Some experiments were carried out in which the yarn mercerized under conditions giving the greatest increase in strength was mercerized again with less tension. The second mercerization differed from the first in that about 15 minutes were required for complete contraction of the yarn in the caustic, whereas the contraction in yarn being mercerized for the first time was complete within two or three minutes. This double

mercerization resulted in yarns having the maximum strength obtainable in a single mercerization and also any desired elongation up to about 10 per cent, depending upon the amount of tension used in the second mercerization. Results of double mercerization experiments are given in Table 1.

It appeared that yarn having the maximum strength but greater elongation might be obtained by other procedures than double mercerization. Thus the yarn could be mercerized under tension in the usual way and the tension then decreased before the yarn is removed from the caustic in order to allow it to contract. Several such procedures were tried. Although it was possible to increase the elongation in this way, the strength was not always equal to that obtained by the double mercerization procedure.

Discussion of Results

The pretreatment given the yarn for these experiments was more thorough than the usual commercial pretreatments; mercerization was carried out with an extremely large volume of fresh, clean caustic solution, and the rinses were very thorough. Consequently, the increases in strength obtained are for what may be considered ideal rather than practical commercial conditions. However, they can be used as a measure of the efficiency of commercial processing.

The pretreatment itself resulted in a very considerable increase in the nominal strength of all yarns of low or medium twist. Whether this pretreatment is essential for the increase obtained by combined pretreatment and mercerization was not determined.

Because of their greater diameter, the pretreated yarns may be of more value for some uses than the mercerized yarns even though the latter are stronger.

The strength of a thoroughly pretreated yarn can be still further increased by suitable mercerization. Unless the twist of the yarn is low, tension of the order of 1 or 2 pounds per 100 ends during mercerization is necessary to obtain this increase, and, even in the case of the low twist yarns, the increase is greater when tension sufficient to prevent the yarn contracting more than

2 or 3 per cent in the caustic bath is used. The time of mercerization, temperature, and concentration of caustic need not be carefully controlled, though somewhat greater strength results when the caustic concentration is low, say 10 per cent, and the temperature is kept at 0° C or even lower.

The results clearly indicate that the twist in the yarn must be low if the maximum increase in nominal strength is to result from mercerization, and if yarns of maximum nominal strength are to be obtained. This effect of twist is so great that an 80's yarn of twist multiplier 2.2 having a strength of only 17 pounds per 100 ends is stronger after pretreatment and mercerization than a similar yarn of twist multiplier 3.0 having an initial strength of 21 pounds per 100 ends. Similarly for plied yarns, where the singles and ply twist are low the increase in strength resulting from mercerization is greater than when the twists are higher. In the case of 80's 2 ply yarns, differing only in twist, the strength of the yarn having low singles and ply twist was doubled as a result of pretreatment and mercerization.

Some reasons for the increase in strength resulting from pretreatment and mercerization may be suggested. It is generally recognized that grey yarns having low twist are weak because of fibre slippage and yarns having high twist are weak because of torsional stresses on the individual fibres. An intermediate twist permits less slippage yet does not introduce undue torsional stresses, and, therefore, results in yarn of maximum strength. This is illustrated by the curve for the untreated yarn in Fig. 4.

Some of the factors which probably contribute to the increased strength of the pretreated and mercerized yarns are increased friction between the fibres, increased strength of the fibres, and better distribution of the load among them.

It is recognized that a better distribution of the load among the fibres may take place during pretreatment and especially during mercerization when the fibres are in a plastic condition, but the extent to which this contributes to the increase in strength is not evident.

The removal during pretreatment of material which lubricates the movement of fibre on fibre, or which does not contribute as much to the strength of the fibre as the same weight of cotton cellulose, would increase the friction between fibres and

increase the ratio of their strength to their weight. The data in Tables 1 and 2 clearly show that the count and diameter of the pretreated yarns of lower twists are greater than the count and diameter of the corresponding grey yarn, that is, the weight per unit length is less and the diameter more. The pretreated yarns feel harsher than the grey indicating an increase in coefficient of friction of the fibres and an examination of the broken ends of the yarns shows that there is less fibre slippage when they are broken than when the grey yarns are broken. These facts indicate that increased friction between the fibres is probably the predominant reason for the increased strength of pretreated yarns.

The low twist yarns mercerized under a tension of 0.2 pound have both smaller diameter and lower count than the corresponding pretreated yarns. (Tables 1 and 2.) This means that the fibres are in closer contact and the area of contact between them has increased. The broken ends of these yarns indicate the absence of fibre slippage. Just as the increase in strength of low twist grey yarns with twist is attributable to decreased fibre slippage, the increased strength of these yarns may be attributed to decreased fibre slippage. The yarns having higher twist did not change much in diameter and count when mercerized under 0.2 pound tension. It is not surprising to note that their strength after mercerization differs but little from that before, since no fibre slippage is observed in either case.

When the yarns were mercerized under the higher tensions they decreased but slightly more in diameter than when mercerized under 0.2 pound tension and changed but little more in count. No evidence of fibre slippage was found by examining the broken ends. However, the strength was in general greater than that of the yarns mercerized under the 0.2 pound tension. The increase would appear to be attributable to an actual increase in fibre strength. The study of how mercerization would increase the strength of the cotton hair is beyond the scope of this paper.

Conclusion

The general conclusion to be drawn from this work is that the strongest mercerized yarn of a given count from a given quality of cotton is obtained under the following conditions:

1. Use of low twist yarn obtained with twist multipliers from 2.2 to 3.
2. Thorough pretreatment of the yarn to remove all extraneous materials.
3. Mercerization at a temperature of 0° C, or lower.
4. Use of sufficient tension during mercerization to prevent the yarn from contracting more than 3 per cent.
5. Use of caustic solution having a concentration of 10 per cent or higher.
6. The time of mercerization to be five minutes.

The resulting yarn should be from 40 to 100 per cent stronger than the original yarn of the same weight.

Acknowledgment

The author is indebted to William D. Appel and Herbert F. Schiefer for assistance in interpreting the results and preparing this report.

References

1. The twist multiplier (M) is a constant relating the number of turns per inch (T) given the yarn in spinning to the yarn count (C) according to the equation $T = M\sqrt{C}$.

2. Unpublished work by the author shows that cotton is appreciably degraded, *i.e.*, the alpha cellulose content is decreased, by mercerization at 100° C with caustic soda solution containing only 0.01% of iron, but that it is not degraded when the iron concentration is less than this amount.

3. The apparatus is more elaborate than would be necessary if it were designed only for the present work. It can be used for the mercerization of skeins as well as of yarn wound on frames.

4. A. B. Corey and H. LeB. Gray. Notes on the preparation of standard cellulose. Eastman Kodak Co., Rochester, N. Y. *Ind. & Eng. Chem.*, 16, pp. 853, 1130, 1924.

5. Skinkle, J. H. Present Practice in Warp Mercerization. *Textile World*, 75, pp. 2377–2378–2427, 1929.

Textile Foundation Researches

Additional subjects that are being studied by research fellows of the Textile Foundation are described non-technically in the reports that follow. Textile Foundation researches similarly described and published previously are as follows: "Effect of Bacteria and Vegetable Oils on Silk"; "Application of Polarized Light to Textile Research"; "Protective Effects in Textile Deterioration and Dye Fastness"; "Spectrophotometric Analysis of Dyed Materials"; "Mildew Prevention and Treatment"; "Orienting Influences of the Benzene Ring."

Moth-repellent Dyestuffs

THE development of moth-repellent textile dyes to provide "built-in" protection against the ravages of clothes moths, which, in this country alone, aggregate annually about $100,000,000, is the object of the study of H. E. Ritchey, Textile Foundation research fellow, who is working at the University of Illinois under the direction of Dr. L. R. Shriner. Mr. Ritchey reports to The Textile Foundation as follows regarding his work and its objectives:

"Some of the multitude of patented mothproofs are ineffective, but the chief loophole for moth attacks probably lies in defective conditions of application. Sprays, for instance, are not applied thoroughly, or fumigants are allowed to escape through lack of air-tight chests or wardrobes. The habits of moths are their greatest protection. They prefer dark places and are seldom seen in the light. The moth that seeks the bright lights and incites the housewife to frantic efforts is usually a harmless variety. His destructive brother works under cover and frequently goes undetected until the damage is discovered.

"There are over six hundred mothproofing materials patented, not including fumigants. Some of the most commonly used substances are paradichlorobenzene, naphthalene, carbon bisulfide and carbon tetrachloride. Of the many materials, some seek to kill the moth, others endeavor to nauseate him and thus divert his presence or his appetite. Some methods probably only lighten the moth's daily routine.

"The great number of 'proofs' attests to the serious need for protection against moth ravages, and would seem to assure adequate defense. In actual practice, however, few of the materials prove entirely satisfactory. Some are inflammable, others poisonous to humans, some malodorous, others difficult to apply, and still others are unsatisfactory because of their expensiveness.

"To be ideal, mothproofing materials should first be effective, have no objectionable odor, should adhere evenly to the fabric treated, be unrecognizable on the material, not dust off, not be toxic to humans, and be reasonably priced.

"Our research problem is to determine whether some of the most nearly ideal moth repellents can be incorporated in dyestuffs. There is only one dye on the market at present that is moth repellent. For practical commercial purposes, and to accomplish widespread mothproofing through such means, it will be necessary to develop a wide range of such dyes.

"The crucial questions which must be settled in our investigations are whether a moth repellent will retain its properties when combined with dyes, and also whether such a combination can be effected without interfering with the qualities of the dyes."

Disposal of Textile Waste Liquors

"DOMESTIC sewage disposal has been handled satisfactorily by sewage treatment plants, but with industrial wastes the high concentration of organic matter and chemicals makes it impossible to apply the same methods of treatment," explains M. S. Campbell, a Textile Foundation research fellow, who is working on the problem of textile waste disposal at the University of North Carolina under Dr. H. G. Baity.

"Because of the large quantities of waste liquors resulting from the bleaching, dyeing and finishing processes," Mr. Campbell continues in summarizing the objective of his investigation, "the textile industry is faced with the necessity of treating its wastes before discharging them into streams or sewage treatment plants. In some localities the problem is quite serious. North Carolina, for instance, has spent much money trying to discover a solution, but no generally successful method has been found.

"Stream discoloration is the most apparent objection to textile wastes, but the effect on the biological life of the stream is the most harmful result. Waste liquors are sterile when discharged from the mills, but are converted by microorganisms in the streams. Organic matter in the wastes serves as food for these organisms, and is finally consumed by them and thus reduced to a stable form. This is the natural self-purification process of streams.

"These waste-consuming microorganisms require oxygen for their life processes just as human beings do. If the quantity of waste is large, the dissolved oxygen of the water is depleted before stabilization of the waste occurs. The result is a septic condition in the stream, foul odors, unsightly appearance, and water generally unfit for domestic or even industrial use.

"Discharging the wastes into sewers and depending upon the sewage treatment plants to care for them is usually unsatisfactory and often disastrous. The majority of sewage disposal plants employ the same microorganisms that the stream depends upon in caring for its pollution. Accordingly, the same limitations apply and the disposal plant often does not adequately clarify or purify the wastes.

"Our research at the University of North Carolina is directed at the determination of textile manufacturing waste disposal methods which will accomplish their purpose efficiently and economically, removing color, organic matter and objectionable chemicals. We must determine whether one method of treatment can be developed to care for all combinations of wastes, whether it is possible to obtain from the process by-products such as fertilizers, gas or even recovered dyes or chemicals that will help defray the costs of disposal, and whether textile waste disposal can be combined satisfactorily with domestic sewage treatment so that municipalities can reasonably be expected to share the expense, as many are willing to do."

Textile Strength and Wearing Qualities

A GROUP of studies on textile strength and wearing qualities is being made at Alabama Polytechnic Institute, Auburn, Ala., by Lawrence B. Haley, who is a Junior research fellow of the Textile Foundation working under the direction of Dr. H. B. Gordon. While this research is highly technical, its "dollars and cents" value is readily apparent. The subject of fabric wear is one angle of Mr. Haley's investigation, which, he explains, is planned "to improve the wearing properties of sheets, wool goods, silk and rayon linings, upholstery and carpeting, and other commonly-used textiles." Complementary to that project is an investigation of the relation between the strength of fibres and the strength of fabrics under varying conditions of wear.

"Fibre strength alone does not insure a strong fabric," Mr. Haley points out in his statement. "A hundred things may happen in converting the fibres to an article of utility, any one of which may bring disorder to normal expectancy. Good, strong fibres premise a quality fabric, but do not assure it. We are endeavoring to determine why the fibre of a respectable family may be perverted in strength of character while being developed into a useful member of the fabric of society."

The third project in this research bears on one or two particular phases of mercerization. "Proper mercerization, we know, strengthens cotton, improves its appearance and adds to its wearing quality," Mr. Haley states. "Our investigations, therefore, are to discover the proper degree of mercerization, the ideally correct chemical solution required, and accurate methods of controlling the process."

Research Committee Meeting

THE meeting of the Research Committee of U. S. Institute, held in Washington, D. C., March 30th, was devoted in large part to the selection of new subjects for study, and to completion of a report on research subjects selected by U. S. Institute that have been completed or are in progress. It was also decided to ask subcommittee chairmen to arrange for the preparation of bibliographies covering research subjects that have been assigned to them.

To fill vacancies on the committee Alban Eavenson and P. A. Johnson were appointed, and the latter was nominated as vice-chairman of the committee subject to confirmation by the Executive Committee.

Abstracts and Bibliography

This section is compiled under the direction of the Committee on Abstracts and Bibliography: Prof. E. R. Schwartz, Chairman, Dr. W. E. Emley, Prof. Louis A. Olney.

The Arrangement

Abstracts and Bibliography are arranged alphabetically by major subject under the following classifications:

I. Fibres (Synthetic and Natural) and Fibre Analysis.

II. Yarns and Fabrics.

III. Chemical and Other Processing (Not Otherwise Classified).

IV. Research Methods and Apparatus.

V. Economic Research and Miscellany.

Subjects are followed by name of author, and the abbreviated or complete title of the publication is followed by the year, volume, issue number or date, and the page number or numbers.

A key to abbreviations of publications abstracted was published in Vol. III, No. 1, Nov., 1932, pp. 58–9, and should be preserved for reference as it will not be published again in this volume. Abbreviations of additional publications abstracted are published in issues of their initial use.

Abstracts

I. Fibres (Synthetic and Natural) and Fibre Analysis

Acetate Silk: Course of Saponification of. R. Haller. *Helv. chim. acta*, 1932, V. 15, P. 1337–41.

The saponification of an acetate silk fibre can be followed microscopically by using alkaline solutions containing azo blue, which stains the regenerated cellulose. When 0.5 *N* NaOH is used, the reaction proceeds intermittently, being interrupted by the cleavage of layers of cellulose from the fibre. However, in 50% alcohol, half-normal NaOH attacks the whole fibre at once. The saponification by other inorganic bases and by various amines also was studied similarly. Alkali carbonates and phosphates saponified the fibres more slowly. Since these reagents are used for this process industrially, textiles of this type must consist of fibres of cellulose having a kernel of cellulose acetate. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1165.) (W)

Aqua-Fibre: Hydro-Activity and Diffusion. Justin Mueller. *Tiba*, 1932, V. 10, P. 991–5; cf. *Chem. Abs.*, 1932, V. 26, P. 6142.

The differences in hydroactivity of different fibres in the same liquid (i.e., bleached and unbleached cotton) evidently cannot be attributed to differences in surface tension. The resistance of fibres to wetting is attributed to foreign (non-fibrous) substances or to "hydroinactivity" which retard diffusion into the fibres. The mechanism of the action of wetting agents is considered to be due to their increasing the diffusive power of aqueous liquids. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1179.) (W)

An Artificial Material. J. Eggert. *Kunststoffe*, August, October, 1932, V. 22: 169–72, 230–2.

A general discussion of the reactions involved is given together with details regarding the preparation of alkali cellulose. A typical x-ray photograph of hydrocellulose from regenerated viscose is shown. Sulfiding or preparation of the xanthogenates, swelling of the xanthogenates, working the mass into artificial products and the after-handling of the precipitated mass are discussed. (Copied complete from *Eastman Kodak Abs. Bull.*, January, 1933.) (S)

Artificial Wool: A Misnomer. S. G. Barker. *Wool Rec.*, 1932, V. 42, P. 1287–8.

The following comparisons are drawn of the characteristics of wool and of cellulose: nature of molecular links; arrangements of micelles in the fibres; linkage between the micelles; configuration of the micelles; behaviour of the micelles on stretching; setting of extended fibres; biological differences; internal structure; comparative weights of the fibre substance; water absorption; strength when wet. (Copied complete from *J. T. I.* abs. section, 1933, Vol. 24, No. 2.) (S)

MICELLAR STRUCTURE OF FIBRES: THE EFFECT OF PRECIPITATION PROCESSES ON. (German) R. Klaus. *Die Kunstseide*, Jan., 1933, P. 9.

It is very important to investigate the influence of the various precipitation processes in shrink- and stretch-spinning on the micellar structure of the fibres. The micelles form the so-called backbone of the cellulose, and the more or less pronounced orientation of the micelles determines a number of different properties which are characteristic features of the cellulose hydrate filaments so formed. (S)

RAYON: CHARDONNET OR NITRATE. E. Berl. *Chim. et Ind.*, 1932, V. 28, P. 1272–6.

After a brief historical review of the invention of Chardonnet rayon, the reasons for its displacement by other kinds of rayon are given and recent progress in the technology of its production are outlined, showing that, particularly for low deniers, it can be produced at a cost and of a quality to meet all requirements of the market at the present time. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1179.) (W)

WOOLS: REPORT TO THE NEW ZEALAND GOVERNMENT ON ENGLISH LEICESTER (38s/42s), ROMNEY (44s/46s), ROMNEY (46s/48s), AND CORRIEDALE (50s/56s). A. F. Barker. *J. T. I.*, Feb., 1933, P. T57.

A study worth the attention of the American mill man, as a good example of the sort of tests needed for comparisons of wool manufacturing qualities. The paper deals with the sorted qualities, fibre diameters, fibre cross sectional shape, of the raw wools. The fleeces were then scoured, prepared for worsted spinning by combing only and also by carding and combing. The tops were spun into yarn, woven into fabric, and the cloth scoured, and finally milled by several different processes. The data on micro analysis of the fibre and the quantitative tests on area shrinkage after milling, are of interest. It is stated, for example, that prepared worsteds give greater contraction than carded worsteds; carded worsteds give greater contraction than carded woolens; long fibred cloths give, relatively, more scouring shrinkage than short fibred cloths; and that short fibred cloths give, relatively, more milling contraction than long fibred cloths. (S)

II. YARNS AND FABRICS

CREASING OF TEXTILES: ON THE. (German) H. Hart. *Die Kunstseide*, Dec., 1932, P. 409.

The internal and external factors which cause creasing of textile goods are discussed. Rayon is especially explained in this respect. The micellar structure of rayon is dealt with in detail, and the close connection between the orientation of the micelles and the creasing properties is shown. Finally, it is shown how creasing may be reduced or completely avoided. (S)

ELECTROSTATIC BEHAVIOR OF ACETA-, SETILOSE-, CELANESE-, NITROACETATE- AND HIGH ACETYL ACETATE-ARTIFICIAL SILK THREAD: REGARDING THE. M. Speter. *Kunststoffe*, Aug., 1932, P. 181–2.

Any of the above threads when rubbed with the hand become strongly negatively charged, while when rubbed with glazed paper the charge is

strongly positive. When acetate film is rubbed slowly it becomes negatively, and when rubbed rapidly, positively charged. The reason for this difference between thread and film is not clear. (Copied complete from *Eastman Kodak Abs. Bull.*, January, 1933.) (S)

TWIST: AN INTRODUCTION TO THE MICRO-ANALYSIS OF YARN. E. R. Schwarz. *J. T. I.*, Mar., 1933, P. T105.

The paper describes a rational method for examination of the structural factors in single and plied yarns, and compares existing conditions with theoretical or ideal cases. In addition to the mathematical discussion, the work includes a tabulated summary of yarn structures up to and including 30-ply noting the inherent defects in certain of these. Further description covers the technique of certain micro-analyses developed in the Textile Microscopy Laboratory of M. I. T. by the author. (S)

III. CHEMICAL AND OTHER PROCESSING (NOT OTHERWISE CLASSIFIED)

DYEING OF BEMBERG SILK. 1. U. Miyaoka and T. Tsubota. *Abstracts Japan. Chem. Lit.*, 1932, V. 6, P. 324; cf. *Chem. Abs.*, 1933, V. 27, P. 1179.

The absorptive powers of Bemberg silk for dyes were measured with varying concentrations of dyes and assistants at different temperatures and times. Prolonged dyeing with heating of the silk, which has absorbed the maximum amount of dye, causes the silk to throw off the dye once absorbed, facilitates the uniform distribution of the dye, and gives the silk a stronger color-absorptive power than other fibres. Hence such silk is superior to others in the amount of dye required to obtain the same shade, the efficiency of the dyeing and the consumption of fuel. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1513.) (W)

EMULSIFYING AGENTS AND THEIR TECHNICAL APPLICATION. W. Clayton. *Mfg. Chem.*, Dec., 1932, P. 313–6.

The technical application of the following materials that are used as emulsifying agents is discussed: Powdered inorganic substances like alumina, clay, metallic oxides, etc.; the water-soluble gums, acacia, tragacanth; the soaps, sodium, potassium and the ethanol amines; proteins, albumin, gelatin, casein; sugars, glycol esters, diglycol oleate and stearate and the sulfonated oils. (Copied complete from *Eastman Kodak Co. Abs. Bull.*, Jan., 1933.) (S)

SOAP SOLUTIONS: ALKALINITY OF DILUTE. I. Davidsohn. *Chem. Umschau Fette, Öle, Wachse u. Harze*, 1932, V. 29, P. 275–6.

Author cites examples, which confirm the experimental results of others, that the presence of small amounts (0.1%) of free alkali in soaps is insignificant in comparison to the total alkalinity due to the normal hydrolysis of soap solutions. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1223.)

SULPHONATED HIGHER FATTY ALCOHOLS FOR RAYON PROCESSING: IMPORTANCE OF. (German) H. Stadlinger. *Die Kunstseide*, Dec., 1932, P. 398.

After a survey of the chemistry, technology and history of the sulphonated higher fatty alcohols the author discusses in detail the advantages

in the textile technique realized by the use of these products—in contrast to that of ordinary soap—in the preparing, washing, bleaching, dyeing and brightening of rayon. In a further paragraph "Practical examples" the manifold and most simple possibilities of application of the new sulphonates in the case of hard water are explained. Continued in January, 1933, P. 22. (S)

SULFUR DYES: CONSTITUTION AND SYSTEMATIC CLASSIFICATION OF. H. E. Fierz-David. *Natur.*, 1932, V. 20, P. 945–7.

A classification with structural formulas is given for sulfur dyes. The first group, thiazoles with a "vat" group, also analogous thiophenes, has anthrayellow GC, Indanthrene yellow, Cibanone blue 3 GF, Immedial yellow G. The second group, thiazine dyes (*Chem. Abs.*, V. 26, P. 2981) has pure blue (Cassella), Pyrogene Indigo (Ciba), Hydron Blue (I. G.), Pyrogene Green (Ciba). The third group consists of the black sulfur dyes and is little known as to structure. This also holds for the fourth group: the indanthrene olives. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1513.) (W)

VISCOSE RAYON AND COTTON: COMPARATIVE STUDIES OF ABSORPTIVE POWER FOR SUBTANTIVE DYES OF. U. Miyaoka and T. Tsubota. *Shikisen (Dyeing)*, 1931, V. 2, P. 209–14; *Abstracts Japan. Chem. Lit.*, 1932, V. 6, P. 125–6.

Contrary to previous notions, viscose rayon has less absorptive power than cotton. To obtain even dyeing of a mixed fabric of rayon and cotton, addition of an assistant is required; otherwise the absorptive power for dyes of cotton is greater than that of rayon. Assistants increase the absorptive power of both materials; with 10% assistant the color absorption becomes equal; with 30% or more, equal amounts of dyes are absorbed in light colors; but in moderate or deep color, rayon absorbs more dye than does cotton. With additions of less than 30% of assistant the absorption of dyes increases rapidly, above 30% it increases slowly. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1179.) (W)

VISCOSE SILK AND DIRECT COLORS: EFFECTS OF ADDITION OF PENETRANT. K. Tatsuki and S. Minami. *Shikisen (Dyeing)*, 1932, V. 3, P. 269–84; *Abstracts Japan. Chem. Lit.*, 1932, V. 6, P. 324.

Effects of addition of nine kinds of penetrant upon the absorbing power of silk for dyes were measured. Addition of a small quantity of penetrant causes lowering of surface tension of water and solution. Maximum lowering is reached with addition of 0.1 to 1.0 gram per liter of solution; beyond this the lowering is almost constant. In general, most penetrants increase the absorbing power of silk for dyes with increase in concentration, and facilitate the solution of dyestuffs, which results in even dyeing. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1179.) (W)

WEIGHTED SILK: QUANTITATIVE ESTIMATION OF SILK FIBROIN IN. Eleanor Fisher and Rachel Edgar. *Iowa State College J. Sci.*, 1932, V. 7, No. 1, P. 1–12.

A review of the literature including 68 references and tables showing ash content and nitrogen content of various silks is included. Four tables

of data based on experiments show that, under standard tests, weighted silks lose an appreciable amount of nitrogen when treated with water, but lose no nitrogen when treated with acid or alkali. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1515.) (W)

WETTING AND AUXILIARY AGENTS: TENTATIVE CLASSIFICATION OF. J. Vallée. *Tiba*, 1932, V. 10, P. 995–1001.

These products are classified as : (1) Substances which are only wetting agents; (2) mixtures of naphthalene derivatives belonging to (1) with solvents; (3) mixtures of naphthalene derivatives belonging to (1) with soaps and solvents; (4) soaps; (5) hydrocarbonated soaps; (6) sulforicinoleates and sulfonated derivatives of ricinolein; (7) substances belonging to (6) mixed with solvents; (8) sulfonated fatty acid, derivatives thereof and mixtures. A large number of the commercial products at present on the market are listed under the above group and the products most suitable for the various treatments of the different fibres (cotton, wool, rayon) are indicated. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 1180.) (W)

IV. RESEARCH METHODS AND APPARATUS

BALANCES FOR THE TEXTILE INDUSTRY. Roller Smith Co. *Instruments*, 1932, V. 5, No. 8, P. 201.

Textile materials are being generally evaluated on the basis of weight per unit length of the thread. Weight of thread per unit length is also often required in determining weight per yard of cloth, or weight of yarn skeins of standard length. To take into account the effect of moisture on the thread sample being weighed these balances can be provided with an auxiliary movement in the same case but independent of the main movement. The auxiliary movement is calibrated so that it reads zero when a weight of 100 mg. is on the hook. It reads directly any increase in this weight up to 20 mg. Therefore, a sample of the same material being studied is made to weigh 100 mg., bone dry. It is hung on the auxiliary hook and when dry indicates zero. It will regain an amount of moisture equal to that of the test sample, provided both are exposed long enough to the same atmospheric conditions. The reading of the auxiliary movement then indicates directly the percent of moisture in the sample. To calculate the weight bone dry or at any desired percent is, therefore, a simple matter. (S)

CELLULOSE MATERIALS: TESTING OF. *J. Ind. and Eng. Chem.*, 1933, V. 11, No. 2, P. 26.

The British Department of Scientific and Industrial Research has issued a 46-page report entitled "The Viscosity of Cellulose Solutions," containing the recommendations of a subcommittee of their Fabrics Research Committee which was appointed to consider the adoption for industrial purposes of a uniform method of determining the viscosity of solutions of cellulose and of expressing the results. The method suggested is very similar to one which was presented at the meeting of the Technical Association of the Pulp and Paper Industry in New York last February, and which was published in the *Paper Trade Journal* of May 12, 1932. (S)

COLOR MEASUREMENT, TWO NEW INSTRUMENTS FOR: SPECIAL INTEGRATOR AND AN OPTIMAL COLORIMETER. S. Rosch. *Ber. VIIIth Intern. Congress of Photography, Dresden,* 1931, P. 150.

In the special integrator, photometric methods are used to measure the product of physical intensity times fundamental sensitiveness integrated over the whole visible spectrum, so that the spectral intensity distribution of the actual or theoretical color stimulus is given by a cut-out figure. The optimal colorimeter compares the test with a chosen variable optimal color, which is obtained by spectral separation from the same light source as is used to illuminate the test. The data read off are direct slit widths sp., mean wave lengths of the optimal color λ_m and relative brightness H_r of the test color. Any color can be localized in the color diagram by triangular figures. (Copied complete from *Eastman Kodak Abs. Bull.,* Nov.–Dec., 1932.) (S)

COTTON STAPLING: USE OF A STANDARD SHEET FOR RECORDING THE RESULTS FOR THE "COMBINED STAPLING TEST." A. W. Hayes. *J. T. I.,* Feb., 1933, P. T90.

A valuable addition to the discussion of precision cotton stapling to be found in *J. T. I.* for February, 1932. One worthwhile feature to be noted is the method for correcting for the length of the staple array, when this length differs (as it normally will) from one sample to another. (S)

SCREENS: LUMINOPHOR REFLEX COPYING. *Phot. J.,* June, 1932, P. 278; *Brit. J. Phot.,* July 29, 1932, P. 466–7; *Nature,* July 16, 1932, P. 88–9.

A phosphorescent screen, for use as light source in the reflex copying of documents, etc. (Playertype process) marketed by Luminophor Ltd., is 'excited' by exposure to light for a few minutes. Screens are available in sizes from 4¾ by 3½ inches to 16 by 12 inches. (Copied complete from *Eastman Kodak Abs. Bull.,* Nov.–Dec., 1932.) (S)

WOOL: THE ESTIMATION OF WATER IN, BY DISTILLATION. C. O. M. Steward. *J. T. I.,* Feb., 1933, P. T98.

The method outlined is compared with the usual conditioning oven technique. The results by distillation are usually somewhat higher. Since the oven is known to leave perhaps 0.5% moisture in the sample, the new method would appear to have merit. The cost of the apparatus is less, and for small samples of wool, the time consumed is not so great. (S)

YARN PROPERTIES, UNIFORMITY, YARN NUMBER VARIATION, THICKNESS AND THIN PLACES, IN LONG LENGTHS OF MOVING YARN: GRAPHICAL DETERMINATION OF. (German) W. Schroeder. *Die Kunstseide,* Jan., 1933, P. 30.

The article is a contribution by Dr. Viviani discussing the above article which appeared in the September number on page 306, and which was abstracted in *Textile Research,* 1932, Vol. III, 2, This is a description of a perfected form of the mercury capillary tube method described by Viviani in *Kunstseide* for August and September, 1911, and abstracted in the *U. S. I. T. R. Bull.,* 1931, Vol. I, 7. A photograph of the apparatus together with several of the photographically recorded charts will be found included in the current discussion. (S)

V. Economics and Miscellany

Daylight: Artificial. (German) F. A. Forster. *Die Kunstseide,* Jan., 1933, P. 18.

The article deals with the influence of light and illumination on the unmistakable identification of colors, both the different effects of daylight, and especially the widely divergent effects of illumination from artificial light sources with respect to identification and distinction of colors, being discussed in detail. Later on, after mentioning the well-known AGELINDUS daylight-apparatus, the new OSRAM–PHILIPS daylight-apparatus is described, which, of all artificial light sources with the character of daylight, hitherto known, is claimed to be the most perfect. (S)

Bibliography

I. Fibres (Synthetic and Natural) and Fibre Analysis

Cellulose: Hygroscopic Moisture of. IX. Hygroscopic Moisture of Silk and Wool. S. Oguri. *J. Soc. Chem. Ind.* (Japan) *Suppl. Binding,* 1932, V. 35, P. 478–81; cf. *Chem. Abs.,* 1932, V. 26, P. 6120.

Tables and curves are given to show the absorption of water by silk and wool at various relative humidities and the calculated heat of sorption. (Copied complete from *Chem. Abs.,* 1933, V. 27, P. 1180.) (W)

Cellulose: Synthetic. K. Roos. *Brit. Plastics,* 1932, V. 4, P. 31–2.

This article, the first of a series, describes the growth of world consumption of timber and envisages a cellulose shortage. (Copied complete from *Eastman Kodak Abs. Bull.,* Nov.–Dec., 1932.) (S)

Celluloses: Analysis and Some Properties of Benzyl. L. Meunier and M. Gonford. *Rev. gén. mat. plast.,* V. 8, P. 427–35, 467–73, August, September, 1932.

(Copied complete from *Eastman Kodak Abs. Bull.,* Jan., 1933.) (S)

Cellulose Symposium: Biological Introduction to the. G. van Iterson, Jr. *Chem. W'blad.,* 1933, V. 30, P. 2–19.

A review (79 references) of present knowledge and theory of the molecular structure, röntgenography, and physical properties of cellulose fibres. (Copied complete from *Chem. Abs.,* 1933, V. 27, P. 1504.) (W)

Cellulose from the Colloid Chemistry Standpoint. H. R. Kruyt. *Chem. W'blad.,* 1933, V. 30, P. 24–6; *Chem. Abs.,* 1933, V. 27, P. 1256.

A review. (W)

Cotton: Influence of Ash Constituents on the Electrical Conduction of. A. C. Walker and M. H. Quell. *J. T. I.,* Mar., 1933, P. T123.

Washing the fiber with solutions of potassium and sodium sulphate may improve the insulation properties from 40 to 100 times. (S)

II. Yarns and Fabrics

Rayon: On the Strength and Elasticity of, in Relation to the Duration of the Strain. (German) Dr. Zart. *Die Kunstseide,* Feb., 1933, P. 42.

New results of experiments on the strength of rayon when loaded for long periods, and on its elasticity when jerkily stretched rapidly and immediately released, are described. (S)

Rayon Dressings and Their Testing: A Summary of. (German) Herman Geier. *Die Kunstseide,* Dec., 1932, P. 426.

A brief discussion of the means and materials used in preparing rayon yarns for weaving, together with a simple method of testing the treated strands. (S)

Viscose Rayon: Cross-section Shape and Dyeing Properties of. (German) A. Jager. *Die Kunstseide,* Jan., 1933, P. 2; Feb., 1933, P. 38.

Continuation of the article "Studies on viscose cross-sections." The influence of the degree of ripening, the drawing-off, the composition of the viscose solution and the spinning-bath on the form of the cross-section and the dyeing capacity are examined. The series will be continued. (S)

III. Chemical and Other Processing (Not Otherwise Classified)

Dyes Derived from Quinoxaline-2, 3-Dicarboxylic Acid. P. C. Dutta. *Ber.,* 1932, V. 65B, P. 1791–3; *Chem. Abs.,* 1933, V. 27, P. 984.

A study of the phthaleins obtained by the condensation of this acid with various aromatic amines and hydroxyl compounds. (W)

Dyes Derived from Acenaphthenequinone and Isatin; Fluorenoacenaphthazines and Fluorenoindazines. P. C. Dutta. *Ber.,* 1932, V. 65B, P. 1793; *Chem. Abs.,* 1933, V. 27, P. 984. (W)

pH Control, and Its Importance in the Processing of Textiles: Simplified. W. R. Kenney and A. B. Reed. *Tex. Col.,* 1932, 54, P. 731–3, 780.

The significance of pH, action of buffer solutions, methods of determining pH values (including a list of dyes commonly used as indicators classified according to pH range) and applications of pH control in textile wet processing are discussed. (Copied complete from *Chem. Abs.,* 1933, 27, P. 605.) (W)

Waterproofing of Fabrics. R. Chesneau. *Tiba,* 1932, 10, P. 669–73, 761–7.

A discussion of the various processes based on the use of cellulose derivatives, rubber, drying oils, paraffin, aluminum salts, copper salts, alginates, gelatin, casein and lanolin. (Copied complete from *Chem. Abs.,* 1932, 27, P. 606.) (W)

IV. Research Methods and Apparatus

Apparatus for Taking Photomicrographs: Simple. M. H. Stow. *Science,* Sept. 23, 1932, P. 277.

A Leica camera is focused for infinity and held over the microscope ocular by a stand. The microscope is focused visually before photography. (Copied complete from *Eastman Kodak Abs. Bull.,* Jan., 1933.) (S)

Cotton Fibres: Test for Chemically Damaged. J. W. Lewis. *J. T. I.,* Mar., 1933, P. T122.

A simple test employing sodium zincate under a microscope. (S)

Photomicrographic Magnification Scale. C. Turner. *Camera Craft,* Dec., 1932, V. 39, P. 495–7.

The construction and use of a scale for determining the magnification of a photomicrographic set-up is described, and a table of magnification and scale readings for various combinations of oculars and objectives is given. (Copied complete from *Eastman Kodak Abs. Bull.,* January, 1933.) (S)

Planimeter: A Simple. *India Rubber World,* 1933, V. 87, No. 5, P. 32.

An illustrated brief description of the use of a common penknife as a reasonably accurate planimeter. (S)

V. Economics and Miscellany

Atmospheric Control in the Textile Industry. R. H. Brown. *Proc. A. S. T. M.,* 1932, V. 32, Part II, P. 733–42; *Chem. Abs.,* 1933, V. 27, P. 1514. (W)

Finishing Plant: Efficiency in a. A. C. Estey. *Tex. Col.,* 1932, 54, P. 734–7.

Many suggestions are given for increasing the efficiency in a finishing plant engaged in processing cotton, rayon, and silk goods. (Copied complete from *Chem. Abs.,* 1932, 27, P. 606.) (W)

Publications Abstracted

A Key to Abbreviations of Publications Used in Abstracts and Bibliography

(Continued from March Issue)

Bull. soc. chim. .....*Bulletin de la société chimique de France*
Chem. Umschau Fette, Öle, Wachse u. Harze .....*Chemische Umschau auf dem Gebiete der Fette, Öle, Wachse und Harze*
J. Econ. Entomol. .....*Journal of Economic Entomology*
J. Ind. Hyg. .....*Journal of Industrial Hygiene*
Mfg. Chem. .....*Manufacturing Chemist*
Rev. gen. sci. .....*Revue générale des sciences pures et appliquées*
Wool Rec. .....*Wool Record and Textile World*